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NASA AUTHORIZATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

FIRST SESSION

ON

AUTHORIZATION OF APPROPRIATIONS FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION FOR FISCAL YEAR 1988

FEBRUARY 3, 19, 26, MARCH 5, AND APRIL 29, 1987

Printed for the use of the
Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE
73-245 O WASHINGTON : 1987

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S261-57

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NASA AUTHORIZATION

TUESDAY, FEBRUARY 3, 1987

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:40 a.m., in room SR-253, Russell Senate Office Building, Hon. Donald W. Riegle, Jr. (chairman of the subcommittee) presiding.

Staff members assigned to these hearings: Marty Kress and John Graykowski, professional staff members; and Pete Perkins, minority professional staff member.

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. I have been asked to open this hearing by Don Riegle because he has been detained. I would be happy to yield to my colleague. I have an opening statement. Do you wish to make yours first?

Senator BREAUX. I have no opening statement. I am not even a Member of the Subcommittee, but Dr. Fletcher's testimony is very important, and I wanted to be here as a Member of the full Committee.

Senator PRESSLER. Let me say, Mr. Chairman, we are indeed fortunate to have with us today the NASA Administrator, Dr. James Fletcher, along with Comptroller Tom Newman, as the Subcommittee initiates it budget oversight hearings for fiscal year 1988.

No one can deny that our space program is at the most critical juncture in its history. The Challenger accident is behind us, but the painful memory lingers on. Now, we are in the midst of a recovery program that pervades almost every aspect of NASA and its institution. Yet, it is encouraging to observe that NASA is making steady progress, as evidenced at this Subcommittee's recent hearings on the Solid Rocket Motor Redesign.

Nevertheless, in spite of this progress, there are still many difficult issues that confront our Aernonautical and Space Programs. One that I find particularly troublesome is the unavoidable delay in the launch of many of our Space Science and Applications missions. It is my view that these delays will have a very long-term negative effect and will inevitably affect the health of Space Science research at NASA and our universities.

Furthermore, I am concerned that this lack of access to space for Space Science and Applications missions will make it increasingly difficult for NASA and our universities to attract and maintain the critical mass of creative scientists who are crucial to the health of NASA. The vitality of our Nation's Aeronautical and Space Programs is a direct function of the quality of personnel at NASA. We must elevate as a top priority at NASA the recruitment and retention of the most qualified scientists and engineers available.

Related to this issue of access to space for our Space Science and Applications missions could be the most significant issue before us today; how and to what extent we develop a "mixed fleet" for our civil space program. There appears to be no way around the fact that NASA must, at a minimum, procure some ELV services, if we have any hope of truly distinguishing our civilian space program from that of other nations.

Certainly there will be a significant cost associated with the development of a mixed fleet, but this is an issue that we cannot ignore as we determine the scope and direction of our future Space Program.

Similarly, with the Department of Defense taking the lead in the development of a Heavy-Lift Vehicle, it is incumbent upon NASA to determine soon to what extent, if any, it will require such a capability.

As for the Space Station Program, it is regrettable that negotiations with the international participants have reached a standstill, particularly as the contract award process is about to begin. Also, just as significant is the publicized growth in the development cost of the Space Station from the $8 billion to $12 billion.

I am not suggesting that the Congress or the American Public will reject a Space Station whose development cost is $12 billion, but now is the time for NASA to clearly define a $12 billion capability versus an $8 billion capability.

That is one of the questions I look forward to hearing a response to today.

I had an excellent meeting yesterday with Dr. Fletcher and others, and got started on that discussion. Also, I am very anxious to explore NASA's decision to delay until 1992 the launch of the Mars Observer Spacecraft.

Certainly the pressures associated with this decision have been great, given the complexities of each of the upcoming Planetary Missions. Nevertheless, this Committee has gone on record in the Fiscal Year 1987 NASA Authorization Bill Report as supporting a 1990 launch of the Mars Observer Spacecraft.

Today's hearing will give NASA the opportunity to discuss its prioritization of the four upcoming Planetary Missions—Galileo, Ulysses, Magellan, and the Mars Observer.

These are but a few of the issues that confront NASA and this Subcommittee. There are many others, such as international cooperation versus international competition, the health of NASA's aeronautical research and development, and the commercial development of space. The difficulty in satisfactorily addressing all of these issues is only exacerbated by the ever-present pressures to control our Federal deficit.

On the issue of international competition versus cooperation, I would like to include in the record by reference a January 18, 1987 Associated Press article which highlights the progress of our competitors—The European Space Agency, Canada, the Soviety Union, Japan, China and Brazil—are making in their respective space programs. While it is clear that the United States space program is no longer the only game in town, this article points out just how rapidly other nations are closing the margin of our once-unchallenged superiority.

NASA's budget request of $9.5 billion is, in some respects, quite positive. Within the context of our Federal Budget, it reflects a noteworthy growth from the fiscal year 1987 appropriation, if the special appropriation for the replacement orbiter is excluded.

However, whether this budget will jump-start NASA into an unchallenged position of superiority, much as we enjoyed during the Apollo period, is arguable. Everyone wants NASA to be the unquestioned leader in aeronautics and space, but defining the term "leadership" in this budget context poses a problem.

Mr. Chairman, in closing, I would also like to state how pleased I am over the inclusion of two new programs in this fiscal year 1988 budget request, the Global Geoscience Space Program and the Civilian Space Technology Initiative, both of which will contribute significantly to their respective disciplines.

With these thoughts in mind, I will conclude my opening remarks and welcome Dr. Fletcher and Mr. Newman to this hearing.

OPENING STATEMENT BY SENATOR GORE

Senator **Gore**. Thank you, very much. Dr. Fletcher, as has already been explained, our Chairman has been delayed and will be arriving soon.

I would like to briefly commend him and the Staff of this Subcommittee for scheduling this hearing as soon as possible after the details of the proposed budget for NASA were made available.

Regardless of everything else, a crucial issue for America's future in space is the amount of resources we are willing to allocate to it and how those resources will be spent. Unfortunately, a review of this budget proposal does little to allay some of the concerns that I have had about the Nation's space policy and NASA's role in implementing this policy. This proposal raises a good many more questions than it answers.

Hopefully, this hearing will help to provide some of those answers.

We must seek to determine whether or not this budget is really sufficient to do what NASA says it intends to do. We need to explore further the goals which NASA sets forth and how the various spending options in this budget would serve those goals.

In doing so, of course, we must not look not only at 1987 and 1988, but beyond to ever more difficult choices. The need to make these difficult choices over spending highlights is perhaps the central problem affecting NASA and the entire future of America in space. It is almost impossible to make these difficult choices without the slightest idea of what the ultimate role of NASA shall be in America's future in space. What are the long-term goals? What is the proper relationship in allocation of scarce resources between NASA and the Department of Defense?

What priority is to be given space science, advanced research and development, communications technology and the other competing programs?

My concern is that without a concensus as to NASA's mission throughout the next decade, we will try to do a little bit of everything and do nothing very well. We can look back from the Shuttle disaster and see what began to happen to the Agency as the Apollo Program came to a close. The tragedy of the Shuttle would be magnified if we did not look back and learn from our recent past in order to chart a course to the future.

I look forward to exploring some of these questions during the hearing today, and I, too, want to welcome you, and thank you, Mr. Chairman.

OPENING STATEMENT BY SENATOR RIEGLE

Senator RIEGLE. Thank you, Senator Gore. Dr. Fletcher, and others who are here now, we are caught in a situation today where we have multiple meetings occurring simultaneously, different committees in different buildings. I had to make a brief appearance in the Finance Committee. Senator Bentsen, who, of course, is the Chairman of that Committee, also is a Member of our Subcommittee, very much wants to be here as he has an intense interest in the Space Program, as do we all.

He has asked me to indicate that he would attempt to get here when he can, although he is chairing this other hearing. I want to thank you all for your patience this morning. Senator Hollings also has another commitment but has a statement for the record.

Let me say at the outset, Dr. Fletcher, that I appreciate the letter that Senator Hollings and I received from you yesterday with respect to some of the issues raised in our last hearing here, specifically on the issue of the solid rocket motor redesign. We are considering that letter and reviewing it and will be back in touch with you, but I thank you for your prompt response in that area.

I will say that, when we had our initial meeting, we met the new NASA management team, and Commander Hauck, who will head the next Shuttle Flight, and we reviewed together the progress that has been made in implementing the Rogers Commissions' recommendations.

Today we want to understand clearly what your operating plan is. We would like you to be certain to detail for us and bring to the top of the list problems, difficulties that you see. We want our oversight to be thorough and helpful. So I hope that you will feel free to take us to whatever problem areas there are, because usually if we know about difficulties we can work together to find answers to solve them.

We are very interested in understanding how you see the mix issue, in terms of different competing activities within this very difficult timeframe when we have a lot of work backed up, once we begin to fly. We are interested in hearing your presentation in terms of your budget submission, and we would like to ask you to proceed at this time.

This morning we will receive testimony from Dr. Fletcher and Mr. Thomas Newman, the Comptroller of NASA. The purpose of today's hearing is to examine closely the budget that NASA has submitted to the Congress in light of its needs both current and future. I would like to say at the outset that I am troubled by a number of the items in the budget. I fear that NASA has not come forward with a document that reflects its true needs.

NASA and the entire space program are at a critical point. We must make decisions in the very near future on a host of issues that are both short and long term in nature, but are all very costly. These issues range from the space station to expendable launch vehicles; from space science to the repair of the shuttle.

Looking at the NASA budget before us today, I am not comfortable nor satisfied that it addresses all of these concerns. We all know, for example, that NASA will need to purchase expendable launch vehicles. The Department of Defense has already announced the purchase of the medium lift ELV's and appears ready to purchase a heavy lift vehicle. But I don't see anything in this budget request for the purchase of the ELV's by NASA.

I have heard that OMB indicated that NASA can purchase the ELV's but the money must be found in the existing funding envelope for fiscal year 1988. I am interested in learning whether that is true, and where NASA will find the first year funding requirements of $600 million. It is not easy for any agency, much less NASA, to find an extra $600 million within existing programs . . .

Space station is another area of interest and concern to me. We are behind the Russians today, and falling further behind. The rest of the free world is looking to the United States with the expectation that they will participate in our station, that they can pursue their goals in space with our platform. But they won't wait forever, and while space station does receive an increase, it is apparent that the projected cost will be far in excess of the $8 billion originally forecast, so this increase will not come close to putting the station on its schedule. Furthermore, it is clear that the administration is not fully in support of the Space Station Program, since OMB cut NASA's original request for the third straight year. There is an unmistakable analogy which can be drawn between this program and the early years of the Space Shuttle Program—and that cannot be allowed to happen.

Space science appears to suffer the largest reductions, and again I am concerned and dismayed. This is a program which has given so much to this Nation, and the course we are on is nothing less than slow strangulation. We have not launched an interplanetary mission since 1977—one full decade; and according to the schedule before us we won't be launching another one for two years—and that is if all goes well. The Mars Explorer will be delayed two more years. And the Advanced Communications Technology Satellite [ACTS] Program is cancelled in this proposed budget. This is a program that Congress has repeatedly stated its intention to continue, it represents the next generation in communications technology, and there is no earthly reason that it should be cancelled at this point in its development.

We are undercutting a vital aspect of NASA's charter, and I am not certain anyone can project the long-term effects of these cuts for years to come—we are losing so much in terms of knowledge, scientific talent, competitive position, and money, since delays invariably mean cost increases.

So, we do have critical decisions before us which will have a major impact upon the course and quality of this Nation's Space Program, not simply for the next year, but for many years to come. Space offers so much to us as a nation, in terms of commercial opportunities, scientific understanding, and the excitement of exploration, but to realize our goals, we must not permit the program to drift aimlessly, rather we must take bold steps forward, toward identified goals, and with a firm understanding of the costs of reaching those goals, and that is what this and the series of hearings we will hold this year hopes to achieve.

Senator Kerry?

OPENING STATEMENT BY SENATOR KERRY

Senator KERRY. Mr. Chairman, while the purpose of today's hearing is review of the Agency budget for fiscal year 1988, I would like to take this opportunity to commend Dr. Fletcher and the men and women in NASA for the job they have done over the last year to get the Agency and the American space program moving again.

The tremendous demands to meet immediate priorities like agency re-organization and the shuttle fix are well known and I think the NASA response is commendable.

But today I would like to reiterate a concern which has been expressed by others here before. The administration has failed to enunciate a clear, comprehensive space policy for this nation.

The NASA Budget submitted by the President reflects a certain lack of direction and uniform commitment to an integrated, internationally competitive space program. We lack vision. Rather than on overall plan around which our domestic and military space programs can be drawn and developed, we have what appears as a patchwork of programs.

I don't believe this is the budget of a nation committed to its space program. It is dangerously "more of the same". I think it may be characterized as the same pattern which you in NASA and the Roger's Commission have identified as partially causal to the Challenger tragedy. Namely, a partial commitment, with stretched out, underfunded programs.

In considering this budget and the choices we must make here and in other programs, it is imperative that we recognize a straightforward reality. Unnecessary fiscal constraint in areas which offer us opportunities for economic growth and continued competitive superiority are false economies.

If we are to have a sustained, vital leadership in space, science and commercial technologies, I think we have to act to articulate that commitment, and fund it. All indications are that the American people are ready to meet that challenge.

In reviewing this budget, I wish to express a particular concern with what is happening to science programs in the NASA program. While all the agency programs are experiencing painful delays as a result of the current down time, science appears to be taking an extraordinarily hard hit. Critical, specific programs from the Hubble Space Telescope to the Galileo mission to Jupiter, the Magellan mission to Venus, the Mars Observer, the Upper Atmosphere Research Satellite, and others have been bumped way back in the launch manifest. These major program delays mean extended financial reductions and lost initiatives.

While we all recognize that certain NASA satellites and DOD payloads have necesssary priorities on that manifest, we also know that today's National Security definition must include scientific excellence and leadership as well as commercial advances if we are to stay competitive in the international economy. I'm not sure it's wise for our space science initiatives to be asked to absorb the burden of U.S. program delays.

These delays mean we are losing and will continue to lose the many bright, committed science students, faculty and professionals who are so important to our space effort. This situation will prevail until we domonstrate a solid, steady commitment to space science.

With this in mind, I would like to commend the Civil Space Technology Initiative included in this budget although I regret that many of the monies therein come from consolidating a number of existing programs. The foresight in recognizing the need to invest in the research for these long term technological advances is heartening. It is exactly this kind of initiative in crucial areas like propulsion which will keep this nation ahead in the world's space race.

There is another concern I would like to mention this morning. Congress had indicated its commitment to the next generation of communications technology in the ACTs program for several years now. NASA continues to zero it. ACTs is a major communications step which, if abandoned by the United States will be picked up by the competition from other nations. The administration repeatedly claims that the private sector will carry this program with independent funds. The industry and congress repeatedly rejoin that such a claim is off the mark. Backing off from our previous investment in the program now would be bad economics and poor policy.

I know that much if not most of the subcommittee focus this year will, of need, be on the issue of our space transportation system. In addition to the Shuttle modifications and Block II modifications a great deal of time will undoubtedly be spent on NASA's plans for Expendable Launch Vehicle acquisition. The results of NASA's own in house study on the long term need for a mixed, reliable launch capacity would be welcome as this subcommittee responds to the budget and deliberates its own recommendations.

There is also need to hear more on plans and budget for the Space Station. It is noteworthy that the level here is far below NASA's initial request to OMB to keep this program moving in a timely way. I hope that the delay in RFPs for Space Station this week is not a reflection of ambivalence regarding the program. If it is, this hearing is the place to hear those concerns and discuss the policy and budget implications of those concerns.

We all know the fiscal constraints under which we in the congress are considering each and every program this year. We also know that these budget constraints will be faced for some time to come.

America's space program has brought us challenge and accomplishment. It has brought us anguish and pride. Today it brings us unique opportunity and it is that opportunity the fiscal year 1988 NASA budget should express.

[The statement follows:]

OPENING STATEMENT BY THE CHAIRMAN

During the course of the last 12 months, the Congress, oftentimes without the vocal support of the White House, has tried to provide additional funding to put the civilian space program back on track and to correct the technical and managerial deficiencies that were to blame for the *Challenger* tragedy. Despite the fact a combined total of $2.9 billion in additional NASA funding was provided in the fiscal year 1986 urgent supplemental and fiscal year 1987 continuing resolution, we all were well aware of the fact that we only had performed triage and that major surgery was still required.

Today, Dr. Fletcher will present the fiscal year 1988 NASA Budget request to the Subcommittee on Science, Technology, and Space. He will inform us of the resource requirements of the civilian space program and he will present us with a diagnosis of the overall health and well-being of the agency.

As we assess NASA's fiscal year 1988 Budget Request, it is important that we thoroughly understand the details of this request and their consequences because the fiscal year 1988 budget request lays the foundation for the future of the nation's space program. It also is important that we realize there are two critical issues not addressed in this request, issues that we must resolve in an expeditious manner—NASA's expendable launch vehicle requirements and NASA's role in the recently announced DOD Heavylift Vehicle Program.

At the outset, I would like to note that I am pleased to see the creation of the civilian Advanced Space Technology Program and the request for 625 new personnel slots. These items represent the seedcorn that NASA must start to sow if they are to attract America's bright young minds and if they are to ensure the technology base required for future space missions.

As recently as two weeks ago at the subcommittee Shuttle oversight hearing, I indicated that I was willing to find the revenues to fund the civilian space program and I am sure the American public shares this sentiment. For too long, I have watched NASA try to put ten pounds of potatoes into a five pound bag. The Challenger tragedy revealed many deficiencies but they weren't all NASA deficiencies. For too long, the White House and the Congress have been trying to get more and more out of NASA for less and less of an investment. Well, now is the time for all of us to show just how deep our support of the civilian space program really is. Now is the time to "realistically" assess NASA's budget, the future scope and direction of our space program, and to make the necessary decisions and provide the necessary resources.

This authorizing Committee is where the process starts and where the catastrophic health care program for NASA and the civilian space program begins. When I voted to provide money for triage last year, it wasn't in lieu of surgery. It was to keep the agency running until we had thoroughly diagnosed the space program and determined what type of surgery was required. After we thoroughly review the fiscal year 1988 NASA budget request, we will know what needs to be done—and I intend to make sure NASA and our civilian space program gets the proper care and attention.

Dr. Fletcher and Mr. Newman, I look forward to your testimony today and to working with you to restore the civilian space program to its former stature and to maintain U.S. technological leadership in space.

Senator **RIEGLE**. Dr. Fletcher.

STATEMENT OF HON. JAMES C. FLETCHER, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY C. THOMAS NEWMAN; DALE MYERS; RICHARD TRULY; BURTON EDELSON; ANDREW STOFAN; JUNE BROWN; GEORGE RODNEY; RAY COLLADAY; PHILLIP CULBERTSON; AND ROBERT ALLER

Dr. **FLETCHER**. Thank you, Mr. Chairman. I think first of all I would like to say that my statement is pretty long, and I expect this will be a comprehensive hearing on the entire budget and we have many problems, as both Senator Gore and Senator Pressler have indicated. I would like to submit this long statement for the record, and just sort of summarize it if that is all right.

Senator RIEGLE. By all means.

Dr. FLETCHER. I would like to say that we have a large group at the table this morning because we anticipate a broad range of questions. I would like to reintroduce Admiral Dick Truly, who is the Associate Administrator for Space Flight. Tommy Newman, as already mentioned, our Comptroller; Dale Myers, my deputy; Andy Stofan, the Associate Administrator for Space Station; and we have Burt Edelson this morning, an old-timer, and he will answer questions on the status of the science, which some of you addressed earlier.

We also have—couldn't get everybody at the table—others. June Brown, I know is able to answer your questions, or follow-on questions to personnel issues which you raised in our last meeting. We also have George Rodney, who is Associate Administrator for Safety, Reliability, Maintainability and Quality Assurance. I know some of your questions will be in that area.

We have Phil Culbertson and Ray Colladay, on Aeronautics, and we have Bob Aller, who is the new Associate Administrator for Space Operations. So we have a separated team, but nevertheless, we have all the people necessary to answer your questions.

If you would like, I would then try to summarize my statement and try to emphasize where I can some of the issues that you have brought up already.

First of all, I am pleased to be here to present NASA's Fiscal Year 1988 budget to you. It is not an expansive budget, as you properly pointed out. It is a pretty tight budget in view of the problems that we have. I am not sure that we have everything in it that we would like in it.

Six months ago when I accepted the Rogers Commission Report on the Challenger accident, I pledged to take whatever actions necessary to make NASA a better organized, better managed, more competent, safety agency, thereby restoring the excellence that has been its hallmark for nearly three decades.

Today, I am pleased to report that NASA is on the way towards realizing those goals, but we are not there yet. A year after the Challenger accident, we have turned the corner in our recovery efforts. Difficult though the past year has been, it has also been a year of rebuilding and a year of strengthening our resolve to the return to the Nation to the forefront of space activities, safely and reliably.

As you know, we have recently announced a comprehensive NASA management reorganization, based on the recommendations of the Phillips Task Force. We are preparing in a safe and orderly way for the resumption of Shuttle flights next February, a year from now, and for the initiation of the development phase of the Space Station during Fiscal Year 1987. We are continuing our Space Science and Applications and other programs, so vital to the expansion of human knowledge. I will come back to that in a minute. We are further strengthening the technology base upon which our leadership in space and aeronautics depends.

President Reagan's fiscal year 1988 budget request of $9.481 billion provides for a strong space program, conceived in an environment of considerable fiscal restraint.

In fiscal year 1988, we will continue to give priority to returning the Shuttle to flight status. We will concentrate upon continued correction of the defects which have been found in the solid rocket booster, and the weaknesses and other elements of the system, and on testing the modified systems, particularly the solid rockets, to assure that they can be safely flown.

Also included is further implementation of the recommendations of the Rogers Commission to enhance our ability to sustain a safe and effective operation of the Shuttle. These activities are well underway on our schedule to permit safe flight on or about February of 1988. Production of an orbiter to replace the Challenger will be in progress using the full funding that was appropriated, as you recall, in Fiscal Year 1987.

Space Transportation Operations funding supports a Fiscal Year 1988 launch schedule of four flights, with nine flights planned for the following Fiscal Year and ten planned for fiscal year 1990. These are planning figures only. We are only going to fly at that rate if we feel it is safe to do so.

NASA's Office of Space Flight, at my direction, has recently completed an analysis of the role of Expendable Launch Vehicles, as was mentioned earlier, as a complementary launch capability to the STS to assure future U.S. access to space. The findings of the Mixed Fleet Study are that Expendable Launch Vehicles could provide a viable and necessary augmentation in the overall launch capabilities of the U.S. Government. However, no final policy determination as been made as of this date as to the number of types of vehicles which might be sought for NASA missions, and no funding has been provided in the Fiscal Year 1988 budget to accommodate a Mixed Fleet Program.

Now, with your permission, I would like to turn to page three of the statement and read what I think is an important statement. As you know, last year, we focused a lot in our discussions on the Safety, Reliability and Quality Program, and I think I want to highlight today what we are doing in this area.

NASA's Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) has been consolidated and expanded under a new Associate Administrator, whom I just introduced, with an increased Fiscal Year 1988 budget request of $16.2 million, and that is about double what it was in fiscal year 1986. However, dollars don't always do it.

Additional funding is planned, in part, to revitalize NASA's basic safety program and to create an Agency-wide systems assurance function which, among other things, will provide a capability for problem reporting, corrective action and trend analysis. These are new things that we haven't been doing well in the past.

The broad data base provided by this system will generate information to be used for the design, flight and test reviews and will be accessible by NASA and its contractors on an iterative basis. That is, we will keep feeding back that information to both NASA and its contractors.

Its trend analysis capability will provide early and more complete illumination of problems for senior management, namely Dale Myers and myself. Major new initiatives are also underway in risk management policies and assessments, advanced non-destructive evaluation techniques, Failure Modes and Effects Analysis (FMEA), as we call it—Critical Items List (CIL) and Hazards Analysis (HA), and flight and ground operational safety.

Other objectives include enhancement of contract provisions and incentive-award-fee criteria for SRM&QA and consolidation of SRM&QA functions at various NASA Centers. I took a long time on that particular subject because we really have turned the whole place around in terms of our SRM&QA activities.

The Administration continues to place a high priority on the development of a permanently manned Space Station and NASA's fiscal year 1988 budget request of $767 million for the Space Station supports substantial and steady progress in meeting the President's goal of an operational capability in the mid-1990's. We are evaluating the results of an intensive top-to-bottom review, as Senator Pressler mentioned, of Space Station estimated costs to assure that program and funding plans are fully consistent.

The Space Station symbolizes our National determination, shared by the President, the Congress and the American public, to remain undeterred by the tragedy and to continue to explore the frontiers of space.

Moving to Space Science and Applications, NASA's budget continues to develop major projects to study the earth, the solar system and the universe. Although the Challenger accident has delayed the launch of many scientific missions, as was mentioned, their importance to science and to the expansion of human knowledge remains unquestioned. They will be launched as expeditiously as possible, consistent with our capabilities.

Furthermore, we have developed a strategy to carry the Space Science and Applications program through the hiatus in Shuttle flights in a manner which will ensure the maintenance of our critical research base, as well as analysis of data from previous missions, to continue first-class science.

I might just break here and say, we have put forth a program which we call the Vitality Package for Science, but we broke it into pieces. It is aimed at suborbital flights (balloons, research rockets and on-the-ground research) to address the kinds of things that Senator Pressler spoke of earlier, namely to continue to attract the best talent in science in our universities in this country.

This science has always been the hallmark of NASA.

Because of the diminished frequency of Shuttle launches, particularly in the early years of resumed flight, we are carefully considering the options for recovery of the Planetary Program. We will launch each mission as soon as practically possible, consistent with vehicle availability. And that, of course, deals with the question of the Expendable Launch Vehicles.

Our budget includes $25 million for the Global Geospace Science Mission (GGS), a new initiative which will support the full participation of the United States in the International Solar Terrestrial Physics Program (ISTP), an important cooperative effort with the European Space Agency and Japan. The program will involve the launch of a series of spacecraft beginning in 1992, and operating through the decade, to study the basic physics of the earth's magnetosphere and the solar terrestrial relationships.

That is a complicated subject, but nevertheless, very sophisticated solar and earth physics.

In commercial programs, the Fiscal Year 1988 budget supports a greater emphasis on promoting commercial ground-based activities through existing outreach initiatives such as the Technology Utilization Program, and the Centers for Commercial Development of Space. Both are aimed at developing new products and processes, the former for non-aerospace companies, and the latter aimed at commercial development of space.

In fiscal year 1988, a new Civil Space Technology Initiative, nicknamed CSTI (we are good at acronyms at NASA) will begin a major new effort to strengthen the Nation's technical base, and thereby, its competitive posture. The program will be implemented in close cooperation with industry and with expanded university involvement.

It includes research in technologies for safe and efficient access to space, for earth orbiting operations and for supporting science.

Moving to the Aeronautics Research and Technology, that program is focusing on emerging technologies aimed at maintaining U.S. leadership in aviation and enhancing U.S. industrial competitiveness. In fiscal year 1988, emphasis on our computational research will lead to advances in the design of aircraft and propulsion systems with the new Numerical Aerodynamic Simulation capability that is now on-line at the Ames Research Center. I think it will be dedicated sometime late this month or early next.

Also, promising results are expected in research aimed at highly maneuverable aircraft technology, and high-temperature composite engine materials—those materials which promise revolutionary advances in engine thrust-to-weight ratios and efficient supersonic cruise propulsion systems.

In the still higher speed regime, we will continue with the development of technology for hypersonic and transatmospheric flight in support of the National Aero-Space Plane Program. Particular emphasis is on lightweight thermal structures, high-speed propulsion, the so-called SCRAM jet, and development of the computational tools necessary for vehicle design and integration.

Our request for Space Tracking and Data Systems will provide for the continuation of the vital tracking, command, telemetry, communications, data relay and data processing support to meet NASA's flight program, as well as advanced systems requirements. The transition from a ground-base tracking network—these are the overseas stations—to a space-based tracking capability for low earth orbital missions, which began with TDRS-1, is continuing. The next two Tracking and Data Relay Satellites are scheduled for launch in February, when Shuttle operations begin and September 1988. As you recall, one TDRS was lost in the Challenger accident.

The proposed fiscal year 1988 Construction of Facilities Program will continue to preserve and enhance NASA's facilities so as to maintain our research, development and testing capability and effectiveness. This budget includes key pacing facility requirements for the Space Station development, essential institutional requirements for R&D, testing and operational support, and the initial increment of a program to assure environmental compliance. We are stepping up to the environmental problems throughout NASA, and part of our Facilities Program deals with this environmental compliance issue—an urgent issue at NASA.

The nurturing and strengthening of our Facilities Base is a fundamental prerequisite in NASA's continuing contribution to the Nation's overall technical competitiveness.

Moving to the institutional area, we will be taking two major steps in fiscal year 1988: Continuing implementation of the organizational changes we announced on January 9th, and increasing the NASA civil service ceiling. The revised NASA organization reflects the results of the eight-month management study, headed by General Phillips, under the auspices of the National Academy of Public Administration, which made an objective and comprehensive assessment of NASA's management practices and their overall effectiveness.

The study's recommendations are designed to improve the management of our technical programs and also improve the management of the NASA institution and our human resources.

The actions we have taken, and will be taking to implement the changes over the next year, enable us to focus more clearly on our goals and objectives, and achieve what we set out to do more efficiently and more effectively.

Now, in closing, I would again like to state that the high level of support that NASA has received from this Committee, particularly, over the last year, has been invaluable in the successful implementation of our recovery program. We are very grateful for that support and for the support that we have received from the Congress as a whole, as well as from the American people.

Today, more than ever, NASA is determined to be worthy of that support. With renewed dedication to excellence, we will strive to make America proud and to maintain our leadership in aeronautics and space. The American people deserve and expect no less.

Mr. Chairman, that completes my statement and we all would be pleased to answer any questions you might have at this time.

[The statement follows:]

STATEMENT OF DR. JAMES C. FLETCHER, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and distinguished Members of the Subcommittee. I am pleased to appear before you to present NASA's fiscal year 1988 budget request to Congress.

Six months ago, when I accepted the Rogers Commission report on the Challenger accident, I pledged to take whatever actions necessary to make NASA a better organized, better managed, more competent, safer agency, thereby restoring the excellence that has been its hallmark for nearly three decades.

Today, I am pleased to report that NASA is well on the road toward realizing those goals. A year after the Challenger accident, NASA has turned the corner in its recovery efforts. Gradually, we are getting the space program back on track. Difficult though this past year has been, it also has been a year of rebuilding, and a year of strengthened resolve to return the Nation to the forefront of space activities, safely and reliably. We have moved steadily forward to realize that goal.

We have stablilized our programs and improved the way we manage the Space Shuttle and Space Station programs. We have recently announced a comprehensive NASA management reorganization based on recommendations from the Phillips Committee. This is one more step in strengthening both our technical and institutional base. We are preparing in a careful and orderly way for the resumption of

Shuttle flights in February 1988, and for the initiation of the developmental phase of the Space Station during fiscal year 1987. We are continuing our Science and Applications and other programs so vital to the expansion of human knowledge. We are focusing renewed effort on building the technology base for greater accomplishments in space in the future. And we are further strengthening the technology upon which our leadership in space depends.

President Reagan's fiscal year 1988 budget request for NASA provides for a strong space program conceived in an environment of considerable fiscal restraint. NASA's proposed budget meets the highest priority needs identified during the budget formulation process and provides an effective base for development of a full program to assure United States leadership in space. It reflects the President's strong and continuing commitment to space and aeronautics programs and to achieving a permanently manned presence in space with a Space Station in low Earth orbit. The President has requested a NASA budget totalling $9.481 billion. On a comparable basis, this represents an essential increase over the $10.5 billion in our fiscal year 1987 operating plan, which includes $2.1 billion to fully fund a replacement orbiter for Challenger. NASA's fiscal year 1988 request includes $3.623 billion for Research and Develpment, $4.064 billion for Space Flight, Control, and Data Communications, $195.5 million for Construction of Facilities, and $1.598 billion for Research and Program Management.

In fiscal year 1988, we will continue to give top priority to returning the Shuttle to flight status. The budget request provides $3.7 billion for the Space Transportation System. Activities as part of the Shuttle Production and Operational Capability Program will concentrate upon continued correction of the defects which have been found in the solid rocket booster and the weaknesses in other elements of the system and on testing the modified systems to assure that they can be safely flown. Also included is further implementation of the recommendations of the Rogers Commission to enhance our ability to sustain a safe and effective operation of the Shuttle. These activities are well underway, and are scheduled to permit safe flight in February 1988. Production of an orbiter to replace the Challenger will be in progress using the full funding appropriated in fiscal year 1987. The budget request also provides for the continued lay-in of orbiter spares and replacement of structural spares used in the production of the new orbiter. Space Transportation Operations funding supports a fiscal year 1988 launch schedule of four flights, with nine flights planned for fiscal year 1989, and ten flights planned for fiscal year 1990.

The Space Transportation Capability Development effort reflects an increase in Spacelab operations to accommodate planned return-to-flight activities, and an increase in funding to continue hardware design and development of the Orbital Maneuvering Vehicle (OMV). IUS, TOS, and PAM upper stages will be procured to support major U.S. planetary missions, and for deployment of the remaining TDRS satellites. Payload operations funding will provide support for the Hubble Space Telescope, Galileo, Ulysses, Magellan, the Astro mission, and TDRS. The Advanced Programs effort will support system concept definition and key advanced technology in, among other things, crew systems, geostationary Earth orbital unmanned platforms, reusable Orbital generation shuttles, and continued joint NASA/DOD studies on future launch vehicles.

NASA's Office of Space Flight, at my direction, has recently completed an analysis of the role of expendable launch vehicles as a complementary launch capability to the STS to assure future U.S. access to space. The findings of the "mixed fleet study" are that expendable launch vehicles could provide a viable and necessary augmentation in the overall launch capabilities of the U.S. Government. However, no final policy determination has been made as to the number or types of vehicles which might be sought for NASA missions, and no funding has been provided in the fiscal year 1988 budget to accommodate a mixed fleet program.

NASA's Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) Program has been consolidated and expanded under a new Associate Administrator, with an increased fiscal year 1988 budget request of $16.2 million. Additional funding is planned, in part, to revitalize NASA's basic safety program and to create an agencywide systems assurance function which, among other things, will provide a capability for problem reporting, corrective action and trend analysis. The broad data base provided by this system will generate information to be used for design, flight and test reviews, and will be accessible by NASA and its contractors on an iterative basis. Its trend analysis capability will provide early and more complete illumination of problems for senior management. Major new initiatives are also underway in risk management policies and assessments, advanced non-destructive evaluation techniques, Failure Modes and Effects Analysis/Critical Items List/Hazards Analysis, and flight and ground operational safety. Other objectives include enhancement of contract provisions and incentive-award-fee criteria for SRM&QA and consolidation of SRM&QA functions at various NASA Centers.

The Administration continues to place a high priority on the development of a permanently manned Space Station, and NASA's fiscal year 1988 budget request of $767 million for Space Station supports substantial and steady progress in meeting the President's goal of an operational capability in the mid 1990s. The Space Station is essential to regaining a position of leadership in space for the United States. Its practical benefits will be many—it will be an orbiting laboratory for the conduct of science, the development of new technologies, and the stimulation of commercial enterprises. It will provide a facility in space to service and repair spacecraft. It will function as a transportation depot from which spacecraft can depart to geosynchronous orbit and beyond. The lessons learned from operating the Space Station in the 1990s—in life sciences, microgravity sciences, technology, and assembly of large structures—are necessary prerequisites to any future long-duration manned exploratory mission.

Symbolic values of the Space Station, however, may exceed its considerable practicality. It represents the commitment of the United States to a future in space. This future will be intellectually rigorous, technically demanding, and commerically profitable. With the positive response to President Reagan's invitation to friends and allies of the United States to participate in the program, the Station symbolizes our Nation's desire to cooperate with others in mutually beneficial civil space activities. With the Soviet Union already operating two orbiting stations, the Space Station symbolizes the intent of the United States to be second to none in utilizing the diverse capabilities of a permanent human presence in space. Perhaps most importantly, as we steadfastly recover from the loss of Challenge and her crew, the Space Station symbolizes our national determination—shared by the President, the Congress, and the American public—to remain undeterred by the tragedy and to continue to explore the frontiers of space.

The Space Station Program itself, in the past six months, has made substantial progress, and I am confident we are now on the right track. We have completed an extensive, 21-month definition and preliminary design study, supplemented by a critical evaluation of the Station's configuration conducted by a special NASA task force. We have completed a three-year effort in technology development, extensively examined operational factors, and restructured the Program's management. In response to Congressional directives, we have baselined a man-tended capability early in the assembly process, provided for the accommodation of early payloads, and initiated a flight telerobotic servicer program. We have also studied the related subjects of Space Station safety and crew rescue, involved the user communities in design activities and made progress in the international negotiations which will define the Space Station partnership during hardware development and operations. In addition, we are evaluating the results of an intensive top-to-bottom review of Space Station estimated costs based upon the revised configuration to assure that the program and funding plans are fully consistent. For further confidence, we are proceeding with a Program Review by the NASA Advisory Council and an independent cost review. The result of all these activities should be a sound Space Station configuration and a solid understanding of design issues, which will enable NASA to undertake a successful development program.

In Space Science and Applications, NASA's budget continues to develop major projects to study the Earth, the solar system and the universe. Although the Challenger accident has delayed the launch of many scientific missions, their importance to science and to the expansion of human knowledge remains unquestioned, and they will be launched as expeditiously as possible, consistent with our capabilities. Furthermore, we have developed a strategy to carry the Space Science and Applications program through the hiatus in Space Shuttle flights in a manner which will ensure the maintenance of the science base and the continuation of the first class science which has been the hallmark of NASA. Because of the diminished frequency of Shuttle launches, particularly in the early years of resumed flight, we are carefuly considering the options for recovery of the Planetary Program. We will launch each mission as soon as practically possible consistent with vehicle availability. The fiscal year 1988 request of $1508.3 million will provide necessary support to accommodate replanning of major flight projects and smaller payloads under the revised Shuttle manifest. It will ensure maintenance of our critical research base which will provide for exploitation of already operating missions as well as analysis of data from previous missions. The FY 1988 request also supports initiation of efforts to prepare for the Space Station era which is expected to increase the potential for scientific advances many fold; the initiation of the funding in this budget will ensure that we are in a position to make maximum use of the Space Station in the early stages.

The fiscal year 1988 budget supports a viable program of science across the various disciplines, with many international partners. It provides for continued effort on the Hubble Space Telescope, scheduled for launch from the Shuttle in 1988; the telescope will enlarge the volume of the universe viewed by 350 times and will extend our vision back ten billion years, almost to the birth of the universe. It also supports continued development of other major projects, including the Gamma Ray Observatory; the Magellan mission to Venus; the Galileo mission to Jupiter; the Mars Observer; the Upper Atmosphere Research Satellite and the Ulysses Solar Observatory. The Cosmic Background Explorer, which will study the radiation from the birth of the universe, is scheduled for launch in 1989 from Vandenberg Air Force Base on a Delta rocket, which will enable launch of this most important scientific spacecraft only nine months later than planned prior to the Challenger accident. This budget also provides for the resumption of Spacelab missions in early 1989.

The budget includes $25 million for the Global Geospace Science Mission, which will support the full participation of the United States in the International Solar Terrestrial Physics (ISTP) program, an important cooperative effort with the European Space Agency and Japan. The program will involve the launch of a series of spacecraft beginning in 1992 and operating through the decade, to study the basic physics of the Earth's magnetosphere and solar terrestrial relationships. The program will entail the most comprehensive study of the Earth's magnetosphere ever attempted and will increase our understanding of how incoming energy from the Sun is distributed, stored and released.

The fiscal year 1988 budget does not include funding for the Advanced Communications Technology Satellite (ACTS), consistent with the proposed Administration rescission action totalling $26 million for fiscal year 1987. The proposed rescission is part of the Administration's effort to avoid possible competition with the private sector and to minimize Government subsidies for activities more appropriately and effectively undertaken by the private sector.

In Commercial Programs, the fiscal year 1988 budget supports a greater emphasis on promoting commercial ground-based activities, through existing outreach initiatives such as the Technology Utilization program. The use of NASA-developed technology terrestrially will aid non-aerospace companies by familiarizing them with the opportunities for future commercial space involvement. At the same time, it will assist both aerospace and non-aerospace companies already interested in space-based commercial development in future flight-related projects. The program will also support continuation of the Centers for Commercial Development of Space (CCDS), which conduct high technology space-related research aimed at the development of new products and processes having either commercial potential or contributing to new commercial ventures. We will also initiate a sounding rocket program to provide companies opportunities for brief weightless experiment time for projects with commercial potential during the Shuttle downtime and possibly thereafter.

In recent years, considerable concern has been expressed in Congress and elsewhere that this Nation may be, in effect, mortgaging its future in space by living off past technological achievements. In order to continue to ensure United States leadership in space technology, ongoing technology efforts in NASA's fiscal year 1988 Space Research and Technology Program have been augmented by $70 million as part of a new Civil Space Technology Initiative (CSTI). The CSTI will begin a major new effort to strengthen the Nation's technical base and thereby its competitive posture, as well as to rebuild and restore NASA's technical strength. The program will be implemented in close cooperation with industry and with expanded university involvement. It includes research in technologies for safe and efficient access to space, for Earth-orbiting operations, and for supporting science. In transportation, launch vehicle propulsion research will be aimed at reusable, high-performance engines for next-generation vehicles, a new booster technology program will develop options for both liquid rocket hybrid and propulsion systems, and an aerobraking flight experiment will demonstrate use of the atmosphere to slow a vehicle returning to Earth orbit at high velocities. Earth-orbiting operations capability will be enhanced through a continued and expanded effort in automation and robotics. Applications include autonomous systems for control of multiple subsystems in the Space Station; launch system software to replace routine, labor-intensive activities; robotics for remote assembly, repair and servicing of space vehicles; and high capacity power delivery. Supporting technology for science will include efforts in structures research, sensor research for Earth observations and astrophysics, and data research for onboard processing of imaging information. CSTI is an important first step in sustaining United States industrial competitiveness and leadership in space.

Our program of Aeronautics Research and Technology is focusing on emerging technologies aimed at maintaining U.S. leadership in aviation and enhancing U.S. industrial competitiveness. The fiscal year 1988 NASA request for this program is $375 million. During the past year, the X-29 forward-swept wing completed the initial flight envelope expansion; industry began flight tests of the GE/NASA Unducted Fan engine; and significant progress was made in joint research with the Federal Aviation Administration addressing wind shear and collision avoidance systems. This year, flight testing will begin on an advanced high-speed turboprop and the X-wing research aircraft. In fiscal year 1988, emphasis on our computational research will lead to advances in the design of aircraft and propulsion systems with the new Numerical Aerodynamic Simulation capability that is now on line at the Ames Research Center. Also, promising results are expected in research aimed at highly maneuverable aircraft technology and high-temperature composite engine materials—materials that promise revolutionary advances in engine thrust-to-weight ratio and efficient supersonic cruise propulsion systems. In the still higher speed regime, we will continue with the development of technology for hypersonic and transatmospheric flight in support of the National Aero-Space Plane program. Particular emphasis is on lightweight thermal structures, high-speed propulsion, and development of the computational tools necessary for vehicle design and integration.

The fiscal year 1988 request of $967 million for Space Tracking and Data Systems will provide for the continuation of the vital tracking, command, telemetry, communications, data relay and data processing support to meet NASA's flight program, as well as advanced systems requirements. The transition from a ground-based tracking network to a space-based tracking capability for low Earth orbital missions, which began with the TDRS-1, is continuing. The next two Tracking and Data Relay Satellites are scheduled for launch when Shuttle operations resume in February and September 1988. TDRSS will be considered operational when three fully functioning spacecraft are in geosynchronous orbit, and the spacecraft and ground terminal have completed their individual and systems acceptance tests.

The proposed fiscal year 1988 Construction of Facilities program will continue to preserve and enhance NASA's facilities so as to maintain our research, development and testing capability and effectiveness. This budget includes key pacing facility requirements for Space Station development, essential institutional requirements for R&D, testing, and operational support, and the initial increment of a program to assure environmental compliance. The nurturing and strengthening of our facilities base is a fundamental prerequisite in NASA's continuing contribution to the Nation's overall technical competitveness.

In the institutional area, we will be taking two major steps in fiscal year 1988: continuing implementation of the organizational changes we announced on January 9, and increasing the NASA civil service ceiling. The revised NASA organization reflects the results of the eight-month management study headed by General Phillips, under the auspices of the National Academy of Public Administration, that made an objective and comprehensive assessment of NASA's management practices and their overall effectiveness. The study's recommendations are designed to improve management of our technical programs, institution and human resources. The actions we have taken and will be taking to implement the changes recommended will strengthen our organization, enable us to focus more clearly on our goals and objectives and achieve what we set out to do more efficiently and more effectively.

The increase in our civil service ceiling of 625 workyears will bring our complement to 22,425 full-time equivalents. The 625 workyears will provide the increased staffing needed to implement the recommendations of review groups, including the Rogers Commission. The added people will be used in the areas of safety, reliability, quality assurance, program direction, and technical support, as well as to meet resource requirements of the Office of the Inspector General.

The funds associated with the additional civil service ceiling are in NASA's fiscal year 1988 Research and Program Management request. The balance of the funds requested in R&PM will cover a continuation of current levels of support to our centers and programs at anticipated price levels. This includes the research, test, operational and facility support and related goods and services necessary to operate efficienty the NASA installations, as well as the travel funds critical to the effective management and oversight of NASA programs. Funding of the NASA institution at the requested level is critical to providing the manpower and support needed for accomplishing NASA's space and aeronautics activities.

In closing, I would like to state that the high level of support NASA has received from this Committee, in particular, over the past year, has been invaluable in the successful implementation of our recovery program. NASA is very grateful for that support, and for the support it has received from the Congress as a whole as well as from the American people. Today, more than ever, NASA is determined to be worthy of that support. With renewed dedication to excellence, we will strive to make America proud and to mainatin our leadership in aeronautics and space. The American people deserve and expect no less.

Mr. Chairman, this completes my prepared statement. I would be pleased to respond to questions you and other Members of the Subcommittee may have.

Senator RIEGLE. Thank you, Dr. Fletcher. We are going to move along with five-minute time periods here so that we can accommodate the strong interest that we have on the Subcommittee to dig into these matters.

I notice in your statement, for the first time when a reference is made to Space Station and when it is to be operational, that instead of using the date 1994, there has been a change and it now says the mid-1990's. Normally, that means slippage when there is a change in terminology.

Are we to infer that there has been some slippage, or looks like there is some slippage here?

Dr. FLETCHER. Mr. Chairman, that is a very astute observation and it was intentional. In the process of going through our cost estimates, we have decided that because it is a significant over-run, we may indeed have to slip the schedule. Depending on which option we come up with in terms of the Space Station—we are looking at stretching it out, we are looking at phasing it and building it in several phases, or perhaps trimming it down—the date of 1994 may slip, but not significantly. More like a year or two. So when we say 1990's, it is not too far from the 1994 date. In fact, it conceivably could be 1994.

Because of the uncertainty, we just had to be honest with you and say mid-1990's.

Senator RIEGLE. Well, we appreciate the honesty. The problem is that 1994, or later, is a long time from now, and of course, the Soviet Union has a functioning Space Station up there today, and they are moving ahead with the work that can be conducted in that environment that is yielding I am sure gains and benefits for them, scientific and otherwise. I am distressed that we are as far behind as we are, and the appearance that we may slip further behind.

Let me ask you, I understand your point about looking at different Space Station configurations and options. We have thought and talked in terms of an $8 billion program. I take it that we are now talking about a program, however changed, it is likely to cost a good deal more than that. I am hearing figures that might be in the range of $13 billion.

Can you give us your best sense as to the parameters now of the higher cost figures that are being talked about?

Dr. FLETCHER. The $13 billion that you mentioned did get mentioned in one interview in the press, but in actual fact we have more than one estimate within NASA. We are trying to reconcile the different estimates. We felt it prudent to go with an independent estimate, outside of the Space Station activities. So we really haven't firmed up our best guess of the actual costs.

Mr. Chairman, I should add quickly, the facts are in front of us in terms of the cost, but there is a judgment factor and the judgment comes in in two ways; one is, how much reserve should we allow. You can't predict all the problems you are going to run into at the start of the program.

So that is one of the questions; how much reserve should we allow for changes along the way that we don't know, and then also, how much reserve should we allow for changes that will probably occur. Those have to be scrubbed down a lot more before we can give you a figure. But I can say that your estimate is in the ballpark.

Senator RIEGLE. Who is driving that effort at the moment? I understand it is complex and you have other very important things that are going on in terms of fixing the booster rocket and so forth. But, who specifically is in charge of driving the effort of the cost estimates and the options on Space Station?

Dr. FLETCHER. I would like to say that it was me, Mr. Chairman, but Dale Myers, my deputy, has been shepherding that. It had to be either myself or Dale because basically one estimate is coming from the Program Office, itself, Mr. Stofan, and the other estimate is coming from the Comptroller's Office, using different groundrules. So it all comes together at Dale's and my level.

Senator RIEGLE. I want to pursue that at greater length, but I want to move to a related question and I want to stay within our five-minute period so that all of the Members have a chance to be involved here.

I am wondering what kind of 1988 budget submission you made to OMB initially? Can you give us the round numbers in terms of what you originally sought?

Dr. FLETCHER. Yes, we have that data for you, Mr. Chairman. My recollection is that we submitted something like a $.5 billion dollars more. Tommy, you had better give them the figures.

Mr. NEWMAN. When we originally submitted, the appropriation for the orbiter had not been made. If you adjust for that and things like the pay raise, then our submission was just over $10 billion. So the reductions made by OMB from that base were $540 million.

Senator RIEGLE. Is that reduction of a $.5 billion dollars identifiable to one or two main items?

Mr. NEWMAN. Yes, sir. The biggest single item was the reduction of $288 million in the Space Station. We requested $1.055 billion; the budget for you is $767 million.

Senator RIEGLE. So in your best professional judgment as an agency, you asked essentially for a quarter of a billion dollars more for the Space Station work at this time in your submission to OMB, and that was turned down. Is that a fair summary?

Dr. FLETCHER. The Space Station was under review. We were going through the cost review. We requested the same figure as had been in the previous 1988 estimate for the Space Station, and it was that figure that was reduced.

Senator RIEGLE. I gather that initially OMB had proposed cutting it twice that amount, about $.5 billion and if my information is right, Dr. Fletcher, you made an appeal to the President and that reduction was scaled back so that you lost a quarter billion dollars for Space Station, but it was not as bad as OMB had in mind for you initially. Is that basically correct?

Dr. FLETCHER. Mr. Chairman, that is essentially correct.

Senator **Riegle**. Well, we are going to have to talk at length about the Space Station because it seems to me that is the center piece of what is still not a very clear picture of what our future space strategy is. But that, to me, is a very identifiable, important goal and it is one that I think in addition to getting the Shuttle flying again safely, we have to take hold of, and we have to shake it down so we know precisely what we are going to do and why and in what time frame, and what it is going to cost. And we must be realistic about the numbers.

So, I will come back to that in later questions, or in questions for the record.

Let me now turn to Senator Pressler.

Senator **Pressler**. Thank you, very much. Thank you, Dr. Fletcher, for taking the time to come to my office yesterday. I have gotten some of my questions answered, but I want to pursue NASA's decision to delay the Mars Observer from 1990 to 1992. When grouped with the three Planetary Missions that will be ready by 1990—Galileo, Ulysses and Magellan—why did you choose to delay the Mars Observer Mission rather than one of the other three?

Dr. **Fletcher**. The answer to that, Senator Pressler, is fairly straightforward. I am not sure it was the wisest thing, but the obvious choice was to delay the one that was least developed. The Mars Observer had only just started a year or so before, whereas the other ones had already been completed and were waiting launch. It seemed like if you were going to delay anything, you ought to pick on the Mars Observer. I am not sure we should delay anything at this point.

Senator **Pressler**. As a spin-off of that question, how does that affect our cooperation with the Soviet Union? As I understand it, there was the potential for collaboration with the Soviet Union with their mission to the Mars Moon Phobos. Does not this delay, all but eliminate, any meaningful cooperation on those missions?

Dr. **Fletcher**. We have never really had an agreement with the Soviet Union to cooperate on the Mars Mission. This has been discussed at some length and we have not really come to any conclusion because of policy issues at the White House level.

We, to the best of my knowledge, had never planned to cooperate to make the Mars Observer synchronized with the Soviet mission to Phobos. On the other hand, if the policy evolves that we should coooperate closer with the Soviet Union, we will make moves to do that, but not necessarily with the Mars Observer.

I think the Mars—I have forgotten what the Russians call it but the Phobos Mission is scheduled for 1988. It would be very difficult for us to move our Mars Observer to meet that earlier date. I may be wrong on the Russian date, but I think it was 1988. Is that right, Burt?

Dr. **Edelson**. Yes.

Senator **Pressler**. Let me ask some questions on the Heavy-Lift Vehicle issue with DOD. I know that DOD came in a little late with their final decision, but the Department of Defense has requested in its fiscal year 1987 Supplemental Appropriation and in its fiscal year 1988 Budget Request funds to initiate a Heavy-Lift Vehicle Procurement Program.

To what extent has NASA been a party to this present Department of Defense initiative, and should the development of a Heavy-Lift Vehicle be a joint NASA-DOD project? Are there reasons for separate developments?

Dr. **Fletcher**. Well, that is a very good question, Senator Pressler. We have been cooperating with the Department of Defense on what should be the Heavy-Lift Vehicle of the future program, which we call STAS. I have forgotten what it stands for. But, anyway, it is a cooperative program with the Department of Defense to look at new technology and ways of reducing the cost of heavy payloads in the future.

When that study is completed, we expect both of us will be able to use that Heavy-Lift Vehicle. We have a lot of uses for it out in the post-Space Station era.

Senator **Pressler**. Who should develop it? DOD or NASA?

Dr. **Fletcher**. That has not been decided.

Senator **Pressler**. What is your opinion?

Dr. **Fletcher**. My opinion is that that is the President's decision and we would be grateful to do it, if asked.

Senator **Riegle**. He almost said it.

Senator **Pressler**. What conclusion has NASA reached about its own requirements for a Heavy-Lift Vehicle? When would NASA need a Heavy-Lift Vehicle and for what purposes?

Dr. **Fletcher**. Senator Pressler, I should differentiate between a near-term Heavy-Lift Vehicle, which often gets confused with the long-term Heavy-Lift Vehicle which we are studying with the Air Force.

The near-term possibilities for Heavy-Lift Vehicle involve several options, and we may actually go different ways—the Department of Defense and ours. One version of that we call the Shuttle Derived Vehicle (SDV), which in concept, at least, is simply taking the orbiter off of the external tank and putting a cargo carrier on and putting the engines that were on the orbiter onto the cargo carrier.

This would give us about three times the payload that we now can carry with the Shuttle, and would, at least on paper, significantly reduce the cost per pound. But you have to have enough pounds to use 150,000 pound payload.

We are looking very hard at that and it may be that we will go that way and the Air Force may go another way. I would hope, though, that the Air Force and the Department of Defense would take a serious look at the SDV because it seems like it would accommodate most of their requirements for Heavy-Lift Vehicle in the near-term, just as it would ours.

Senator **Pressler**. If I could just ask just one quick follow-up on that subject, it is my last one. What criteria are there in deciding to develop a Heavy-Lift Vehicle using either Shuttle-derived technology or entirely new technologies, and applying those criterion, in which direction is NASA leaning?

Dr. **Fletcher**. Senator Pressler, let me separate the question out in two parts. One is the far-term, which is the study that is going on with the Department of Defense, the so-called STAS. There our requirements are similar. We need to lift something on the order of 150,000–200,000 pounds and the emphasis for both of us will be on low-cost per pound. We have to reduce our transportation costs, we and the Department of Defense, for whatever we want to do in the future. For us, it is primarily going back to the Moon, going to Mars, or building a larger Space Station.

In the case of the near-term, I can only state our requirements because I am not familiar with the near-term requirements of the Department of Defense. Our near-term requirements for something like SDV would be not so much to reduce the cost, but to rather allow larger chunks of the Space Station, for example if we decide to launch it with the Heavy-Lift Vehicle, to be lifted up into orbit, and also to take care of our need for Planetary Missions. We could, with our own SDV, launch two or more Planetary Missions on the same SDV, and beyond that, there are a lot of other possibilities.

By the way, Mr. Myers has been following that. I would like him to comment on what he sees in the future on the SDV. Beyond that, there are a lot of issues having to do with resupply of the Space Station, which a Heavy-Lift Launch Vehicle could do; offload the Shuttle so that we could carry on the Shuttle things that it was designed to do and service the Space Station more adequately.

Dale, do you want to comment further? You are closer to it than I.

Mr. MYERS. I think Jim has covered the general picture. The distinction between the SDV as an early capability, and the later studies that we are doing under the Space Transportation Architectural Study staffs, with the Air Force, is really associated with the issues of advancing the technologies to reduce check-out time, to reduce stay time on the pad, to reduce the number of people that are involved so that you can really make a major reduction in the cost-per-pound orbit, or to bring capability both to NASA and to the military for developing much lower cost transportation to space.

Those are two different elements of the study that are going on. For the near-term requirement, we are coordinating with the military and we will continue to see where the best element of a program would be and what the requirements are. I am sure that will be reviewed very closely.

The longer-term one is a continuing study. It has been going on for a year and a half. The Air Force will continue for another year looking at that long-term Heavy-Lift Launch Vehicle that may result in two-stage fully-recoverable systems, or systems that will bring together the best automatic checkout equipment and the best capabilities technology-wise that can reduce the cost to orbit.

So those two things are still going on.

Senator PRESSLER. My time has run out.

Senator RIEGLE. Senator Gore.

Senator GORE. Dr. Fletcher, thank you for your emphasis during your opening statement on quality control, or SRM&QA. I want to pursue a series of questions with you about quality control, but before doing so and in order to preserve some continuity in the hearings, I would like to follow up on the line of questions just initiated by Senator Pressler.

The Heavy-Lift Vehicle you said should be looked at as a near-term Heavy-Lift capacity and a far-term heavy-lift capacity. Now the total lift capacity of the Shuttle as it is now configured for payload is what?

Dr. **Fletcher**. East-West launch, Senator Gore, approximately 50,000 pounds. Some circumstances, depending on the thrust of the engines, it could be somewhat higher than that.

Senator **Gore**. The medium-term Heavy-Lift Vehicle that we need for the currently foreseeable applications is in the range of 150,000 pounds; correct?

Dr. **Fletcher**. That is correct, yes.

Senator **Gore**. And the far-term heavy-lift capacity would require a lift of how much?

Dr. **Fletcher**. Not much different from the 150,000. I would say 150,000 to 200,000.

Senator **Gore**. So, the 150,000 near-term Heavy-Lift Vehicle could possibly do the heavy-lift job we need for a long time?

Dr. **Fletcher**. Yes, but we would like to reduce the cost.

Senator **Gore**. You need to reduce the cost. I understand.

Now the issue here is whether or not NASA is going to build a Heavy-Lift Vehicle or whether the military is going to build a Heavy-Lift Vehicle. It is unlikely that the Nation will need two Heavy-Lift Vehicles; correct?

Dr. **Fletcher**. Certainly unlikely for the long term, I would agree, Senator Gore.

Senator **Gore**. Now, secondly, is it not true that NASA has a great deal of fixed investment in place, such as test stands, technology base, development teams and the like, which can readily be brought to bear on the development of a heavy-lift capacity. Correct?

Dr. **Fletcher**. That is correct, Senator Gore.

Senator **Gore**. And there is also a plan already worked out to modify the Shuttle to get this so-called Shuttle-Derived Vehicle which will give us approximately 150,000 pounds of lift capacity. Correct?

Dr. **Fletcher**. That is also correct, Senator Gore.

Senator **Gore**. And yet the administration has decided to submit a supplemental request for the Air Force to start from ground zero, with a clean, white sheet of paper, and design from the ground up a brand new Heavy-Lift Vehicle under the aegis of the military, without taking advantage of the years of work and the enormous amount of fixed investment that NASA has already devoted to this task. Correct?

Dr. **Fletcher**. Senator Gore, I think that is the place where I have to clarify. I think it is not at all clear at this time that the proposed early Heavy-Lift Launch Vehicle will not involve NASA and its capability, or it may even be the Shuttle-Derived Vehicle.

Senator **Gore**. But the request is by the Air Force, and Secretary Aldridge has made it very clear that he wants to take a zero-based, white sheet of paper, ground-up approach to a Heavy-Lift Vehicle. Now, I think that is a ridiculous way to proceed.

Let me just say for the record here that as a Member of the Armed Services Committee, I am going to take a very jaundiced view as one Member of that Committee, and I happen to know there are others on the Committee that agree with me, of this supplemental request by the Air Force. If NASA is not going to be in the transport business, with all the other developments that have been going on, NASA might as well shut its doors. And if we are not going to be realistic about the budget contraints we face and begin to set some priorities about—including how we can use capacity that is already developed in the civilian space program, then we are just sticking our heads in the sand.

So I think it would be a very poor decision for the Congress to go along with what the President is recommending here. I want you to know that you are going to have many on this Committee and the Armed Services Committee fighting to preserve NASA's primary role in this area, because NASA should be playing the lead role as America goes into space.

Now, I recognize that in the private councils within the Administration, your view does not always prevail. Sometimes I am glad it does not, but on this occasion I wish that it had. We will be fighting with you on this.

Similarly, I think the question of ELVs speaks to the same exact point. You know from your studies and from the analysis of your mission requirements that you need a mixed fleet, and you will need some ELVs.

Now, my time is up, but if you could respond to this final question on this round, and I will come back to quality control next time; what are you going to do in the area of ELVs given the fact that the Administration has not allowed you to go forward at the kind of pace that many space policy experts have advised us is the right way to go for NASA?

How are you going to correct this problem?

Dr. Fletcher. Senator Gore, the answer has to be a little bit lengthy, if you don't mind. There are three phases of the future that we have to look at. One is the near-term, things that have to be addressed in the Fiscal Year 1988 budget, and we are looking intensively at that and the only thing that we can order for NASA in that period are existing launch vehicles. Even the new medium launch vehicle, as defined by the Air Force, wouldn't apply in that near-term effort. We expect to come forward very soon with our recommendations and hopefully how to pay for them in that period.

The next period that we have to deal with is 1991, when the fourth orbiter is scheduled to be delivered, until we start assembling the Space Station which is in the 1993–1994 period. We are going to have a big backlog to work off and we have to look at all the launch vehicles available to us because we just can't launch everything with the Space Shuttle, there is no way.

That means we have to look at what is available during that period. We probably will not be developing any new vehicles of our own because we already have the Titan IV which is an Air Force development; we will have the medium launch vehicle, which I guess we call the Stretch Delta—I am not sure it has a better name than that; and then of course, we will look at the existing Atlas Centaurs and the existing Deltas.

For the longer term, that is the period when we start putting the Space Station together, and beyond, that is when we have to look at a new vehicle and that is where the Shuttle-Derived Vehicle would come in in our way of thinking. We haven't really focused on that period early because we figured we ought to aim at what we ought to decide in fiscal year 1987 and 1988 first. And I hope we will have something for you very shortly to recommend in that time period. I hope that clarifies it a little bit.

Senator GORE. Than you, Dr. Fletcher.

Senator RIEGLE. Senator Danforth.

Senator DANFORTH. Mr. Chairman, thank you, very much.

Dr. Fletcher, NASA anticipated the launch of the Space Telescope last fall. What are the present plans for that launch, and what is the significance of the Space Telescope program?

Dr. FLETCHER. Senator Danforth, that is an extremely important program because that is the first of our giant observatories, as we call them. There is no other nation in the world that can put such observatories in space because, first of all, you need the large cargo bay that the Shuttle has, and second of all, it needs to be tended because it is a permanent observatory in space.

That particular telescope is in the visible range. It is for things that you can see, and the size of the reflector in the telescope is such that we expect to see something like seven times farther out in space. That is a layman's way of saying it, but nevertheless, stars that are much fainter than anything we can see now by two orders of magnitude.

That should make a huge difference in our understanding of how the universe began, but also it has applications for looking at planets, possible planets of nearby stars. We suspect the planets are there but it would be nice to be able to observe them visibly on a space telescope.

That will be launched on flight number thirty, and I think it is now scheduled for the end of 1988. The Comptroller says November 1988; that assumes the schedule is held.

But anyway it will be the fifth flight—very high priority in NASA's manifest.

Senator DANFORTH. You have heard the current buzzword which is competitiveness—all of us are using it. The President is in the act, Congress is in the act. We are all talking about how to make America more competitive. How do you view NASA's programs and NASA's budget in addressing this national concern?

Dr. FLETCHER. Competitiveness in NASA takes two forms; one is that we want to compete in space, and in aeronautics, too. The things that we are doing in the Space Technology Initiatives and also our Aeronautics R&D Program, I think, will continue to assure that this Nation is first in both aeronautics and space.

Those are the direct applications. I might even add that last year, aerospace exports were the largest single export of this country. I may be wrong but, I think even larger than farm exports. That ought to be checked, but we intend to continue to pursue excellence there and we are competitive in those two arenas.

Now, in addition to that, NASA has for many years had a Technology Transfer Program. That is, transferring technology from the space and aeronautics arena into the commercial sector. We call that the Technology Utilization Program.

That has had outstanding success, not just in terms of the transfer of technology, but in people understanding that NASA is available for that kind of technology. So the technology utilization which was established some 16 or 17 years ago, is now a model for the rest of government.

I noticed that in the President's speech, he indicated that other agencies of government will be asked to do the same thing, and some of them have already started. The SDI Program, for example, has copied our TU program for obvious reasons, because General Abrahamson used to be at NASA.

Senator **Danforth**. Well, if competitiveness is to be our priority, are you satisfied that the NASA budget is sufficient to establish that priority?

Dr. **Fletcher**. I think for competitiveness in aeronautics, our budget is sound and adequate. For competitiveness in Space Science, I think there is something to be desired, but our Civil Space Technology Initiative will address that.

Where we are behind, Senator Danforth, the Soviet Union, and we are rapidly being caught up with by the Europeans, is in the so-called manned space program. There, I think we may have lost the competitive edge. The Soviet Union has had a manned space station up, as somebody mentioned earlier, for some years now, 1973, I believe.

They have all the data on long duration in space, the physiological data. They have the experience of being there permanently in space for a long period of time. So I think we have a ways to go to catch up with the Soviet Union in that particular arena.

Senator **Danforth**. Thank you, Doctor. Thank you, Mr. Chairman.

Senator **Riegle**. Senator Breaux.

Senator **Breaux**. Thank you, very much. Thank you, Dr. Fletcher and your colleagues, for your presentation.

I am a relatively older Member of Congress, but a new Member of the Senate, and certainly a new Member of this Committee, and I look forward to working with you and your goal of bringing NASA up to their full operational capability, a goal that I know, I think, most Americans share.

On page three of your prepared statement, Dr. Fletcher, you went into some of the new initiatives of NASA with regard to basically safety initiatives. You speak to the point that major new initiatives are also underway in risk management policies and assessments advanced non-destructive evaluation techniques, Failure Modes and Effects Analysis/Critical Items List/Hazards Analysis, et cetera.

I guess what I would like you to tell me, at least, in English, what are we talking about? What defects in the prevous system, number one, led to these major initiatives? What are we going to be doing now that we were not doing previously with regard to all of these safety areas?

Dr. **Fletcher**. Senator Breaux, we are doing two things now. We are providing a little better oversight to our plant representatives and various contractors. These are the DCAS people, so-called, supplied by the Defense Department, or the APRO. Basically, we are saying we are going to supply our own people to make sure they do their job, and sometimes we will have our own people in those plants.

That is our people problem, and that is a natural thing to do when you have had an accident, is tighten up your quality control.

But beyond that, we are looking—by the way, there is a significant number of people involved in that; something like 200 civil servants and another 200 support contractors—at an increase in the fiscal year 1988 budget. But in addition to that, those would not have prevented the accident. The accident was caused by some things falling through the cracks, communications procedures and things of that sort.

So George Rodney has invented the term Systems Reliability, and that involves a whole range of different techniques, which I imagine will have been tried for the first time at NASA, although I would like Mr. Rodney to address that.

Nevertheless, these are the SRM&QA techniques that involve more than just the regular SRM&QA that we are used to.

Senator **Breaux**. Are you satisfied basically then that the new procedure would allow a launch, for instance, to be halted because of any one of these checkpoints along the line coming up with a negative launch recommendation? Do we still have a system where you could have one part of that system recommending a no-go and being ignored, or being overruled? Are you confident that that procedure now exists in place so that that negative recommendation from a critical point would be followed and not overriden?

Dr. **Fletcher**. Yes, Senator Breaux. There is a quick answer, and that is yes. But I should quickly add that we have been also extremely careful in tightening up our communications and organization in the Space Transportation Office, itself. Admiral Truly has assigned Captain Bob Crippen to look at all of these procedures and organization, and make sure the chain of command brings that to his attention and it doesn't drop along the way.

That is the main thing that we are doing and that has already been underway. If you want to ask Admiral Truly in detail what he has done, that is a different subject.

What we are saying in terms of Mr. Rodney's office is that we have an independent chain to Dale Myers and myself, so if there is a problem it can come up through that chain, as well. So we have a check not only on the Space Transportation System, but also on the Space Station, as well.

Senator **Breaux**. Well, I know we are all pleased to hear that. Let me ask you on another area. It seems to me, and maybe as a newcomer, that we have changed our philosophy somewhere in mid-course. We talked initially about reusable launch vehicles. Now we are talking in terms of expendable launch vehicles. We talked in terms of reusable launch vehicles versus a Space Station, and now in the budget recommendation there is $700–$800 million this Fiscal Year for construction of a Space Station.

Have we made a determination that we are changing the philosophy in that regard? Is it because we are behind the Soviets in that area? What has led to that recommendation? It seems that this has been a major change in direction.

Dr. **Fletcher**. Your observation is absolutely correct, Senator Breaux, in terms of changing from a one-system way of transportation, namely the Space Shuttle, to a mixed fleet. I think the accident made us all aware of the fact that we ought not be dependent on one article to get us to and from space.

Fortunately, or unfortunately, the only way we have of transporting people to and from space in the Free World is the Space Shuttle. So that will be focused on people transportation, and to the extent that it is possible, we will use it for other missions. But we also have to have a mixed fleet, that means expendable launch vehicles.

So that is a definite shift in our philosophy.

There is no shift in philosophy of the Space Station other than the fact that we are looking at the possibility of resupplying that and maybe even constructing it with an expendable launch vehicle. That study isn't complete, so we haven't really changed that philosophy; we are just looking at it.

Senator **Breaux**. Let me just have a last follow-up, if my colleague from Massachusetts would allow, and that is, with regard to the budget. I mean, I know Louisiana is competing for the initial space contract and you spoke this morning about your recommendations for the money in this budget being rather dramatically reduced by OMB at some point.

My question is, are you satisfied with what is in your budget request if that ultimately is approved? Would the people in Louisiana, or in any State, for instance, be confident that you would have sufficient funds to move to the development stage, starting in 1988 with the amount that you have in the budget now?

Dr. **Fletcher**. Senator Breaux, in view of all the things that have happened, we have had to reconfigure the Space Station once already, and we are considering reconfiguring or at least phasing it, again, because of the possible cost overruns. I think $768 million, or whatever the number was, is an appropriate amount for fiscal year 1988.

The runout for that in the later years may have to increase, and that is the thing we are most worried about.

Senator **Breaux**. Take it one step at a time. Thank you, Mr. Chairman.

Senator **Riegle**. Senator Kerry.

Senator **Kerry**. Thank you, very much, Mr. Chairman. Dr. Fletcher, I would like to take this opportunity to commend you and the folks at NASA for what, as I begin to learn more and more about, your work and this Committee's work I think is a commendable effort both in terms of reorganization, as well as in the Shuttle-fix efforts.

I would like to just take a moment to express a concern, and perhaps have you comment on it generally. I think it has been enunciated by some before, I do not think in the context of the current Congressional and national concern about competitiveness and the expressed concern of the President in his State of the Union Message about competitiveness. I do not think it can be overstated by us, and I would like to say it; and that is, as I learn more about this budget—and I have much more to learn—and as I look at and learn about the tensions between Transportation and DOD and Defense efforts within the NSC, and Commerce, and that whole tug-of-war, that analyzing that affort against this budget, it seems to me we have a budget here which really does not reflect a National commitment to a clear policy with respect to space.

In fact, it may be said by some that this is a budget that falls into the category which you and the Rogers Commission talked about as being partially responsible, as causal with respect to the Shuttle tragedy. That is, that we had a partial commitment with stretched-out under-funded programs.

Now I believe that that kind of fiscal constraint, where we have such clear opportunities for competition and where we see the Europeans and the Japanese and others so clearly prepared to move into a market that we seem to be moving out of, is a fiscal constraint that is a false economy, if you will. I am particularly concerned and want to express a particular concern about what is happening to the science programs within NASA.

I understand, and I think everyone understands that all of the Agency programs are experiencing some very painful delays as a result of the current downtime. But it seems to me that science is taking an unwise and larger degree of that painful process. I think that critical specific programs, from the Hubble Space Telescope, to the Galileo Space Mission, to the Magellan Mission, to the Mars Observer, the Upper Atmosphere Research Satellite, these major programs are going to mean extended financial reductions, lost initiatives, and I think concomitantly are going to mean the loss of students, the loss of scientists, the loss of people who are essential to our competitive efforts.

I wonder if you would not please comment on that. I know it is a long comment, long question. And then I have a follow-up question to that that I would like to ask you about.

Dr. **Fletcher**. Senator Kerry, I think your observations are right on track. We do have the problem of a longer focus. We had focused on the Space Station, but we ought to be looking farther into the future and we expect to come out with some recommendations as to what that future ought to be later this spring, and we have a number of studies going on. But the first crack at that is dealt with in the Civil Space Technology Initiative. These are some things we know we have to do for missions of the future.

Addressing the second part of your question about Space Science, you are quite right, Space Science has really suffered and we are trying to accommodate the difficulties that you described. In the first place, there is not a heck of a lot you can do with those giant observatories. They have to be launched in the Space Shuttle and we will launch them as soon as we can.

For the Planetary Programs, though, we have other options and that is where we are looking very hard at launching some of those Planetary Missions on expendable launch vehicles. We had already made the decision, last year, to launch the Cosmic Background Explorer, which is not planetary, but is out in space a ways, on a Delta Launch Vehicle.

We expect to look very hard at the missions that you identified—Magellan, Galileo, Ulysses and the Mars Observer—on expendable launch vehicles, and do what we can there. In addition to that, we have been aware of the problem, and I came from a university so I know the problem well; you can't get graduate students to move onto a program that doesn't have a future.

So we are trying to put together a program and that is what I meant by the Vitality Package, which we have nicknamed; doing experiments on the ground, reducing data from spacecraft that already are in space operating, or data that is stored somewhere from previous missions, doing sub-orbital flights. This means research rockets where you can test some of the instruments, and you can go up high enough so you can make measurements on the stars, and look down on the Earth, and in addition, our Balloon Program, which people don't talk about too much, except lately because we have decided to reemphasize the scientific experiments that are carried on our balloons.

We have a large balloon facility down in Palestine, Texas. All of these things won't solve the problems, but they will help alleviate the problem of the young Ph.D. student and post-doc student who want to move into science. Any suggestions to further improve it would be welcome.

Senator **Kerry**. Could I ask another question?

Senator **Riegle**. Please do.

Senator **Kerry**. I hear in your answer considerable kind of very polite frustration and reiterate my personal observation; I think that while you are fighting on many fronts and many battles, the administration is missing an enormous opportunity here which we could feel the repercussions of for years to come in terms of those markets that are now available to us, and those new markets we have not yet created.

I think the American people are prepared and always have been prepared and understand and are excited by that kind of opportunity and I hope that we are not going to miss it.

I had the opportunity to have Commander Rick Hauck in my office the other day. We were talking about—and incidentally, we are delighted that you had the wisdom to choose somebody from Massachusetts to be the Commander of the next flight.

Dr. **Fletcher**. Admiral Truly did that.

Senator **Kerry**. Admiral Truly, I congratulate you.

We were talking about, and on the mission that he last came back from, they brought with them a satellite to be fixed. I understand that satellite is now about to be relaunched on China's Long March Missile, which seems to underscore precisely what I am saying.

My question is, what evidence is there that the administration could put forward that the commercial launch ability of the private sector is going to be there, can catch up to or even meet competitors without some kind of transitional assistance from NASA, in a specific plan with specific budgeting for that transitional process?

Is there any evidence to say that we are going to be in that market, or are we going to be going to China and France and other places for these launches?

Dr. **Fletcher**. Senator Kerry, that is another good question. In the process of trying to regroup and get back on track at NASA, the Air Force wisely decided that they ought to go with their own expendable launch vehicles, which consists of two kinds—the Titan IV, which is adequate for our Planetary Missions, for most of them, anyway, and also the medium launch vehicle, which is now called the Stretched Delta.

Those are helping the commercial launch industry. We are a little bit late in saying what our needs are, but we plan to use the vehicles that are already on the books. There are at least two more vehicles that are available; one is the Atlas Centaur, and we could order those, if we chose. Or, we could order the old Titans, the T-34D's which are also on the market.

The idea of us developing our own has been somewhat restrictive because we have focused more on purchasing the launch vehicles for our own needs, except out in the 1990 period, where we may decide to develop our own.

Senator KERRY. I am not thinking so much of your developing your own as much as I am a specifically-targeted transitional type of program to speed us up, if you will. I am not sure, from what I hear—and I think the same thing is true, incidentally, with the Advanced Communications Satellite, the ACTS. I think you zero-funded that, and I am deeply concerned about that, because I think there, again, there is no indication that the private sector has any ability to make up that difference.

Yet, this cry of privatization is governing that decision in a vacuum, if you will, in terms of the ability to really move.

Mr. Chairman, I have long overdone my time, and I apologize.

Senator RIEGLE. Senator Kerry, I think those are important questions and I want to say that I appreciate the active involvement of all the Members of the Subcommittee who obviously bring a very intense interest to this subject matter, as properly we should as a Subcommittee.

So I want to pursue those items with you, and in fact I would like to continue on for a moment with respect to the commercial launch side of where we are going here in the future.

Are you satisfied, Dr. Fletcher, that it really is smart for NASA to be getting out of the commercial launch business, once we work off some of the things that we are already committed to?

Dr. FLETCHER. Mr. Chairman, when you say NASA get out of the commercial launch vehicle business, we are planning to purchase commercial launch services, which is a term that we now use, from the contractors that I mentioned—McDonnell-Douglas, General Dynamics, and Martin-Marietta. These are existing commercial launch vehicles.

We don't plan to purchase services from China, France or places like that, other than commitments that we have already made in the past. The only change is that we are not developing new launch vehicles, except in the 1990 period, that we have considered.

Senator RIEGLE. I probably was not clear. I am probably asking you a different question. I am talking about giving up commercial launch manifests to the private sector. As I understand it, NASA has now reached a decision to basically get out of that business; that we are going to work off some of the ones that we had previously committed to do. Some we are just basically cancelling out, even though we made commitments; we are just leaving private business customers high and dry, so to speak.

As I understand the policy for the future, that we are not going to continue to handle the standard kind of commercial packages and loads that we have in the past.

Am I correct in that?

Dr. FLETCHER. That is pretty close to precise, Mr. Chairman, with one or two exceptions. What was decided by the administration is that we will not launch commercial communications satellites on the Shuttle. That was a decision, as you probably have heard in the rumormill, that we didn't like too well because it meant abrogating some of our commitments. But that decision is made.

Senator **Riegle**. The decision is made for the moment. I do not know that that decision is made for all time. This Administration leaves office in two years, but I do not think that they, by themselves, can make that decision. I think they can participate in the decision but I think the question of whether or not we ought to be stepping out of the commercial launch business and turning this over increasingly to foreign suppliers, in the absence of a domestic industry coming into being, I am not sure that that is a wise decision. I think that is an unwise decision.

But that is a personal view of mine. I am wondering how you feel about the idea of NASA getting out of the commercial launch activity. In the past, we had a balance. We did the scientific launches, we did a certain amount of military launch activity. We certainly did the exploratory activity to the Moon and beyond, and as well, we took up certain major commercial loads for the private sector in the communications area, principally; I thought that was a pretty good mix and thought it made a lot of sense.

Now we are going to get out of that business and I do not frankly see the replacement for it. Are you comfortable with that? Is that really sound policy?

Dr. **Fletcher**. Mr. Chairman, I will have to answer you in two contexts. I felt very uncomfortable about abrogating our contracts. I think there were about six or eight missions that we had to ask to not fly on the Shuttle. That I felt very uneasy about.

On the other hand, we really, on the Shuttle, could not have launched all of the backlog with the Shuttle.

Senator **Riegle**. I understand.

Dr. **Fletcher**. So we can't expect the Shuttle to do everything because we are not flying as many as we only have three orbiters now. But I did feel a little bit upset when the decision was made to abrogate our contracts.

Senator **Riegle**. But I am really asking a broader question. And that is, looking at NASA over the next five years, the next ten years, the next twenty years, should not we consider whether NASA should be in the business of helping to carry up these private sector business activity launches, or not?

I mean, we have done it in the past. I think it has worked well. There is no existing alternative domestically. I mean we can push people off to foreign suppliers. It certainly hurts our balance of payments, and helps to move the technology ahead for other nations rather than ourselves. But, is that sound space policy?

I mean, I am not just talking about kicking people off and reneging on commitments. I am upset about that, too; but should not we be handling some of that business five years out, ten years out, fifteen years out?

Dr. **Fletcher**. Mr. Chairman, you are putting me in a little difficult spot, as you probably know. I work for the President and the President has made his decision.

Senator **Riegle**. Well, you work for the President, but you work for the American people more than you work for any particular person in the Government. You are a professionaL and you have been around this track before. You have worked for other administrations, and we need your best independent judgment.

That is your obligation.

Dr. FLETCHER. Mr. Chairman, I think it is worth looking at, yes. I think we ought to revisit that problem, but I think we ought to give the private sector a chance to see what they can do now that we have made this first decision. There is some evidence that they are going to be able to compete, at least in the short-term.

But I don't like the idea of moving off to Long March, and other possibilities, either. I think we have a serious problem there.

Senator RIEGLE. Well, it seems to me that that is a policy question that needs a much tighter focus and debate, as to whether or not NASA is wise to get out of the commercial launch business. And, if that is the decision, it seems to me that there is a corresponding obligation, and I think a public policy obligation to see to it that a private sector capability, in fact, does get developed in this country and gets developed rapidly. That means dealing with questions like the insurance problems of launches, and there are a host of other issues.

But it seems to me that we are now facing a kind of aggressive international competition, where other nations, and I think wisely so, have seen the commercial possibility of moving into this business area. They are doing so, and obviously there are risks associated with it, but I think they are right in doing it. Also, they see major technological benefits.

I think we have to stay in this business as a Nation. I feel very strongly about it. I do not think we ought to just yank NASA out of it when we do not have an alternative answer for that problem. If our private sector—and we are a private sector economy—if it is going to work properly, it seems to me we ought to be able to accommodate the proper business activity that people in our Nation want to carry out.

If they cannot rely on these massive facilities that we have spent all this money to develop, then something else is going to have to be produced in its place. I think the economies would argue for using what we have and to get the extra mileage out of that. We may have to make some new arrangements along the line here, but it seems to me, if space is just beginning to open up in terms of the commercial possibilities of things that have to be done, for us to step out of that business while other nations are stepping in, it seems to me to be sort of a classic mistake.

I would hope that we would hear and have the chance to discuss that more directly. I am not interested in one particular administration or in one group of people at a point in time making decisions that lock us on course for the next several decades. We cannot make decisions like that in this country, and we should not.

Dr. FLETCHER. Mr. Chairman, I think your points are all well taken and I don't quarrel with them. But I do think we have a chance to get back into that arena in the 1990's with this Shuttle-Derived Vehicle. This has a lot of potential for commercial launches, not that we would provide them, but that the persons supplying the SDV could also sell services to communications satellite customers.

In fact, I think it should be mentioned that the first person, or first group that made a proposal for the Shuttle-Derived Vehicle was Hughes Aircraft Company, who makes about half of the communications satellites in the world. They came to us and to the Air Force and proposed to build their own launch vehicle.

It was not felt appropriate for the Department of Defense, apparently, but nevertheless, that is still on the books, and we are considering it seriously.

Senator **Riegle**. Senator Rockefeller.

Senator **Rockefeller**. Thank you, Mr. Chairman.

Dr. Fletcher, with respect to the Space Sciences matter, the Space and Earth Science Advisory Committee of the National Academy of Scientists has said that we have lost or are losing our pre-eminence in that field to not only to the Soviets, but to the West Europeans. That is a discussion that you and I have had over a number of sessions; that is science as opposed to military uses of space.

The 1988 NASA budget appears to complicate this problem in several respects. One there is the delay of the Mars Mission; two there is the rescission of the $27 million program for the Advanced Communications Technology Satellite Program. There is only one new science program, which is the Global Geospace Science Mission, and there is delayed action on the X-Ray Astronomy Facility, and the Hight Resolution Solar Observatory.

Now, I understand that obviously when something like the Challenger tragedy happens, a lot of things get delayed. Nevertheless, there is also the problem of materials manufacturing, materials processing and that delay.

I would like to have your views on, how in an enhanced budget, you have a reduced planetary exploration and materials processing budget. Now that can be Challenger-caused; it can be NASA-priority caused; or it can be the question of ELVs—other ways of doing it.

I would like to have your views on that apparent shortcoming.

Dr. **Fletcher**. As we have discussed, Senator Rockefeller, your point is again well taken. But let me just comment on the SESAC statement, that we are losing our pre-eminence in science. What I think they should have said, if they didn't say it, is that in some areas of science we may be losing our pre-eminence, but I think it is only proper to say that the U.S. is way ahead of the rest of the world in most areas of space science.

In planetary science, there is nobody close. Nobody has landed any robots on Mars; we have landed two. Nobody has visited the outer planets; we have visited Jupiter I don't know how many times, and we have also visited Saturn several times. We have visited every planet in the solar system at least once, except for Neptune and we plan to visit Neptune in 1989.

There is no other nation in the world that has the great Observatory Program that we have. We are participating and I think we are still leaders in the Solar-Earth Physics Program and global geoscience that is recommended as a new start.

Where your point is well taken is that we maybe haven't addressed as carefully as we ought to have, and put on as high a priority as we ought to have, the so-called emerging science called microgravity science. That is sometimes called material processing, and sometimes called commercial space, and so forth. But we really are increasing our expenditures in this arena in terms of building furnaces, and so forth, that are ready for flight.

I have forgotten the dollars—in fiscal year 1988 it is $46 million for that arena, versus $31 million in 1986, so it is increasing. But your other point is well taken. The only place that we know of that you can effectively perform microgravity science is on a Space Shuttle. You could conceivably have a free-flyer in space that you don't tend, but so far we don't have sophisticated enough furnaces to be able to do that. So far, the furnaces have to be man-tended.

So the Space Shuttle and the Space Station are the appropriate places for that. And because of the accident, we have slipped downstream considerably more than we would like for those missions that involve microgravity research.

We are trying to make up for that lack in a number of different ways. One is that we have smaller secondary payloads, Senator, which are things that don't necessarily go in the payload bay, or if they do they go in what we call GAS cans, "get-away-special" cans, smaller pieces tucked into corners, and things of that sort. And, also, some of the secondary payloads go in the cabin, itself.

That is one thing that we are looking at very hard because we are concerned about the same things you are.

In addition to that, we have a private sector enterprise. We have a memorandum of understanding with—I remember the chief of the company Max Faget—Space Industries, Inc., it is called. Max used to be with NASA, and they are proposing to build a facility of their own, not charging us, for customers that want to use microgravity research for commercial or scientific purposes.

That will be an adjunct to the Space Station, but it could be an adjunct actually to the Space Shuttle. We are looking at that possibility.

Senator **Rockefeller**. But an ELV would not work on materials processing?

Dr. **Fletcher**. I wouldn't want to say that absolutely. I would say we haven't addressed it carefully. But that is probably something we should look into. It wasn't planned for an ELV, Senator. Unless I am mistaken, we have not really examined that possibility. But we will look at it.

Senator **Rockefeller**. Thank you, Mr. Chairman.

Senator **Riegle**. Senator Bentsen.

Senator **Bentsen**. Thank you, very much, Mr. Chairman. I apologize for not hearing all your testimony, Dr. Fletcher, but I have been chairing a hearing over at the Finance Committee.

I want to express my interest and some concern over what I have heard stated thus far. I understand that in responding to Senator Danforth, that you stated that you were no longer confident that we could keep the United States competitive in Space Science; that we are definitely behind the USSR in manned-space programs. Those are very troubling comments and I am sure they concern you a great deal.

Dr. **Fletcher**. Could I interrupt, Senator Bentsen? I think I said that there is not much danger of our losing our pre-eminence in Space Science, only in this one area of Space Science, namely microgravity. But you are absolutely right about the manned-space program.

Senator **Bentsen**. Does not that argue for some reordering of priorities?

Dr. **Fletcher**. It does argue for a more intensive look at the manned-space program. I don't think it is wise for the U.S. to fall that far behind the Soviet Union and possibly other countries in the manned-space arena because we need people in space for a lot of reasons. We are looking, as you know, very hard at what else we ought to do in the manned-space program.

Dr. Sally Ride is heading up an effort within NASA, to make a recommendation to me, and I guess ultimately to you and the White House on what should be the follow-on to the Space Station.

Senator **Bentsen**. Well, I certainly share that concern. Looking down the road, insofar as technicians, engineers, scientists, I am told that the average age is over 50. Obviously, you are going to have to train a successor generation so that we can lead space in the future.

What kind of programs do you have at NASA to attract graduate students? I am concerned about having sufficient academic departments in universities to train future space scientists. Last year, I introduced legislation to establish a Space Grant College Program.

Have you had a chance to review that proposal yet? Do you have any comments on how such programs could enhance NASA's ability to attract skilled personnel?

Dr. **Fletcher**. Our people have looked into the general problem of how we attract students in our program, and we have a number of initiatives in that arena. I will have to ask my colleagues here if they are in the process of looking at the possibility of a Space Grant College Program. I understand well what you mean, but I am not on top of that, Senator Bentsen.

Senator **Bentsen**. Well, let me say at this point that I would strongly urge that you do so and give that consideration. We were talking about a rather modest budgetary commitment in that regard, seed money, in effect, to try to assist in that.

Did you have some comment you wanted to make, Mr. Myers?

Mr. **Myers**. Senator Bentsen, I am aware that we have put a lot of emphasis on the exchange of people from NASA and the universities in the ongoing joint programs, where we exchange people to work in the facilities of NASA, and our people in the facilities of the universities.

I am not specifically aware of this direct grant program, but I think NASA has been a real leader in activities to try to exchange our technologies with those of the universities, and our technologies with industry in the same way.

Senator **Bentsen**. Mr. Myers, I strongly suggest that you do look into it and give it consideration and see if that modest amount of seed money that we are talking about might not be very fruitful in trying to see that we have young people going into those kinds of programs so that you have a spawning ground, that you have an area from which you can draw more talented young people into that program.

We keep talking about the fact that we are not doing enough in higher education to assist in these various fields to remain competitive, and certainly this is one of them that should be in the forefront.

Mr. **Myers**. All right. I will certainly do that.

Senator **Bentsen**. I also understand that earlier you acknowledged that OMB cut $288 million from your Space Station budget request, and that the timetable may have slipped, or the program might be cut back, stretched out, done in stages. What would you have done with that extra $288 million that is not provided in the proposed budget?

Dr. **Fletcher**. For one thing, we would have spent some of it, but I think, Senator Bentsen, it was appropriate, in view of our uncertainty about the costs when we were going through the OMB process, it was appropriate that we stop and take a look at what the real costs were. We have done that. We have two different cost estimates, one developed by the Program Office, and the other one developed by the Comptroller's Office, and each of them are significantly higher than $8 billion that we originally had assumed for the Space Station.

I ought to blame that on my predecessors. I never used the $8 billion figure. But nevertheless, we have to deal with that somehow in terms of the future run-out of our program. We are looking at the various options for doing that.

I think though that the amount of money that was allocated for the Space Station, $768 million or thereabouts, is enough to get us a good start, considering the fact that there are already delays in issuing the RFPs and considering the fact that there are some Congressional restrictions on going ahead without making those cost estimates. Putting all that together, I think $768 million for the first year of the program, or the first development year of the program is a reasonable number.

Senator **Bentsen**. Thank you. I understand my time is expired.

Senator **Riegle**. Senator Bentsen, let me just say that I am interested in the proposal which you have advanced today, and I think we ought not only look at it carefully, but see if we might not be able to schedule a hearing on that and take a look at resources generally, but very particularly the human resources.

So let us work together on that.

Senator **Bentsen**. Thank you, Mr. Chairman.

Senator **Riegle**. Senator Pressler.

Senator **Pressler**. Thank you, and let me say that I am very interested in some of the personnel questions that Senator Bentsen has asked and I will be asking some more questions for the record, because I think the people of NASA are key. I know that some of the salaries are a problem, but also, when people work on a project such as the Mars Observer Project, or other similar projects and suddenly the project is delayed, probably the psychic rewards that they get are lost, and that is something we need to keep in mind, as well.

But in any event, I want to turn to a subject that has not been covered, and that involves, as I understand, the Department of Defense decision to place the Shuttle Launch Complex at Vandenberg on a "minimum caretaker status" until at least 1992. Since the fiscal year 1988 DOD request provides funds for a second Titan IV launch pad at Vandenberg, it would appear that DOD is moving away from a West Coast Shuttle launch capability.

Let me say that I am not from a State that has a launch capability, so I am not into regionalism here; I am trying to determine policy.

If Vandenberg is never activated, how will this affect the design and development of the polar platforms associated with the Space Station, given that we will have no manned servicing capability, and how and to what extent would the absence of a West Coast Shuttle launch capability affect other future NASA missions?

Dr. FLETCHER. Senator Pressler, that is another very good and cogent question. My deputy, Dale Myers, has been in constant negotiation with Air Force on this problem and I would like him to address that question.

Mr. MYERS. Senator Pressler, we have had on-going discussions with the Air Force on the activities on the West Coast. In answer to your first question, the number of launches that are involved with the Shuttle on the West Coast by the military and by NASA is relatively small.

The threat certainly is there. No decision has been made as to the continuation or discontinuation of the Shuttle. It is in this caretaker status, and as far as we are concerned, our plans involve the reestablishment of a launch capability on the West Coast.

However, we in NASA and perhaps more than previously, think more in terms of contingency planning than we have previously, and in the case of our polar orbiting element of the Space Station, we are looking at the use of a Titan launch vehicle as a possible launch vehicle for that activity on the West Coast. It is part of our overall mixed fleet study and we will be reporting on that shortly to you.

Senator PRESSLER. The Committee's fiscal year 1987 NASA Authorization bill report requests NASA to report back to the Committee by February 1, 1987 on NASA's plans for future R&D in land remote sensing. With the future of the LandSat Program looking extremely uncertain, what in fact, are NASA's plans for future land remote sensing R&D?

Dr. FLETCHER. As you know, Senator Pressler, the operational responsibility for our land remote sensing is with the private sector. I have forgotten the name of the company that runs those. In terms of R&Ds, we still have the initiative at NASA, and we have a number of activities, both in the way of developing new instruments for land sensing of various kinds. We have a number of spacecraft for remote sensing. TOPEX is already funding. You can't say land sensing—it is more water-sensing--but it measures the topography of the Earth, a cooperative program with the French.

We also have, of course, the program which we call the EOS, Earth Observation System Program and that is the one that was discussed by Mr. Myers previously, in which we plan to have a complete program, north-south platform, which has a number of instruments which do remote sensing. In fact, that is a kingpin of this new science which is evolving called Earth System Science, in which we are trying to make measurements from space and also on the ground, over the whole globe; not only ourselves, but the rest of the world will have to be involved in that program because some land measurements are required everywhere.

But the EOS is the kingpin of that. Earth Systems Science, by the way, is just a fancy name for global climate as affected by man's activities on the globe.

I think it is very important for the future and we are getting prepared for that. I am sure I left some items out.

Burt, do you want to add to that?

Dr. EDELSON. Dr. Fletcher did cover it correctly. And to just reassure you, Senator Pressler, that the instruments that will fly on the polar platform as part of Project EOS are now under development, and they include such projects as the synthetic aperture radar that we have flown already twice on the Shuttle, and will fly again; and also the imaging spectrometer, which is the principal instrument that will be used in the future for land remote sensing.

Senator PRESSLER. Mr. Chairman, if I could——

Senator RIEGLE. Please continue, Senator Pressler.

Senator PRESSLER. Let me return to my earlier question. I just realized on the Vandenberg question, I wanted your evaluation, Dr. Fletcher, on how and to what extent would the absence of a West Coast Shuttle launch capability affect other future NASA missions?

Dr. FLETCHER. We hope that in the future we will be able to have polar platforms that are man-tended, that is, that are permanently up there and that are visited from time to time with people to maintain them, to upgrade them, new instruments and so forth. That is the primary purpose of the West Coast Shuttle facility for NASA. That is one of the main reasons why it is kept open for a 1992 launch, which is about the time that the EOS—I think I am right—it is about the time the EOS has planned—one year later, I think.

But nevertheless, we hope that continues and we have assurances from the Department of Defense that it will in fact, even though it is mothballed, reopen it in 1992.

Senator RIEGLE. Thank you, Senator Pressler. Senator Gore.

Senator GORE. Thank you, very much. Just to follow up on that; is it true that the Department of Defense has no mission requirements for Vandenberg for the Shuttle right now?

Dr. FLETCHER. I think Dale Myers has been working more closely with DOD than I have.

Mr. MYERS. DOD has some missions that require the Shuttle and the Shuttle can meet those missions. As a result of the Challenger accident, we have had to modify the Shuttle. There has been some additional weight put into the Shuttle to increase its safety, and that decreased some of the performance aspects on the West Coast.

On the other hand, we have reviewed very carefully the missions that DOD would use the Shuttle for out on the West Coast, and we do meet all the individual Shuttle mission requirements that have been established for the Shuttle.

Senator GORE. Well, that appears to conflict with Secretary Aldridge's statement the other day, that they need 109 percent power and a filament wound case and that NASA can provide neither.

Mr. MYERS. As a result of the mothballing of the Shuttle on the West Coast, NASA has stopped the production planning for the filament wound case and we have delayed the 109 percent certification. We have put all our emphasis on the early flights of the Shuttle.

So the testing that we are doing down at Marshall and in the Rocketdyne facilities on the West Coast are associated with 104 percent, and with margins to 109 percent.

We have enough time so that in our planning that when we look at 1992 launch, we can back up from that, continue now the development of the filament wound case, get into the testing of the 109 percent certification of the SSME, and then produce the filament wound case. We see nothing that would cause any safety issues with the filament wound case once we have developed that process.

Senator GORE. It is disconcerting that Secretary Aldridge's view and your view are different, at least in the sense that it produces for him a feeling that NASA cannot meet the mission requirements and therefore there will be no DOD missions. Am I mistaken about that? That is the feeling we get from Secretary Aldridge?

Mr. MYERS. I would like to turn to Admiral Truly, who has had some specific and detailed discussions about this.

Admiral TRULY. Senator Gore, we have continued over the last several months to work with the Department of Defense on performance, particularly at Vandenberg. The two parts of the program that you mentioned, the filament wound case and 109 percent engine, have been major issues.

Unfortunately, after the accident, as Mr. Myers said, we have had to put the filament wound case program on hold. While we had the filament wound case in a structural test at Marshall a few months ago, we sustained a hairline crack in a steel element, not a part of the filament wound case—it had nothing to do with the filament wound case and its integrity—but unfortunately, we had to have that facility for the Shuttle recovery efforts. So we are removing the filament wound case from that effort. But we have not backed away from that development.

When DOD determines that they will ramp up the funding so that Vandenberg will become operational, it is our plan to ramp up the development funding on the filament wound case.

Senator GORE. I understand, but in the meantime, while it stays in this hiatus, what is the annual cost for keeping it in storage? $400 million? What is the——

Admiral TRULY. The Vandenberg launch facility?

Senator GORE. Yes.

Admiral TRULY. It is my understanding that the DOD fiscal year 1988 budget request plans to ramp the Vandenberg launch facility status to a level of about $50 million per year, over the next several years.

Senator GORE. But it will be $400 million annually to maintain it when it is operational?

Admiral TRULY. When it is operational.

Senator GORE. All right. Now I asked questions earlier about the Heavy-Lift Vehicle. I would like to submit more detailed questions, which I hope you will respond to in writing, on this particular issue. Let me just note in passing right here, that last May this Subcommittee was told that it would soon be provided with a preliminary report from the joint NASA/DOD Space Transportation

Architecture Study, the supposed basis of the recent DOD Heavy-Lift Vehicle decision.

We have still not received that, nine or ten months later. Do you know offhand when we can get that?

Dr. FLETCHER. Senator Gore, I guess I was unaware of that date. We have probably been remiss in not getting back to you. We can always give you a status report, where we stand on those studies.

Quite frankly, though, we are not satisfied with those studies. We have been briefed, Mr. Myers and I, several times and we feel that a lot more work needs to be done. So all we can do is give you a report on where we stand, what the options are, and what we are now planning to do in the remaining months of the study, which we would be glad to do.

Senator GORE. That is fine, but the concern I am getting at is, we want a decision like that one to be made in an orderly way, according to the best knowledge that exists, both in NASA and in the Air Force, and elsewhere at DOD, so that it is done carefully and logically.

Instead, it would appear that the study is either woefully inadequate, or hasn't been done or has not been paid any attention, and instead, whoever gets to OMB or whoever is making the decisions down at the White House now, whoever gets their first, gets the money. The rational process does not exist.

So if you could give us that study in whatever form it exists, we would like to analyze it to see how the decision was made.

We still have money in the budget for the joint study. We still have R&D funds for NASA's heavy-lift vehicle, which I strongly support. But we have to make a rational decision. I mean, we are not going to proceed on parallel tracks with no formal order to it.

Now, with the indulgence of the Chairman, let me move to another topic here before getting to quality control.

We had hearings before the Full Committee on the issue of competitiveness, and as you are well aware from the news media, this 100th Congress is going to be making a major push on that large issue of competitiveness. All of the experts are agreed that one of the largest areas of commerical opportunity in the world economy is telecommunications.

The Japanese have their own way of mapping out the future and aggressively pursuing opportunities in the future marketplace.

We have kind of an awkward way of going about it because we are constantly reexamining the question of how government and business relate to one another, what is the proper role of government and all that. We have one program at NASA that appears to be ideally keyed to this Nation's effort to participate in the future of the world telecommunications' market, and that market is going to be measured in the trillions of dollars after the turn of the century. It is already extremely large.

I am referring to the Advanced Communications Technology Satellite. I have talked to some of the people in private industry who are aware of these programs. They tell me absolutely nothing like that is contemplated at all in private industry because the risks are so high. It is the kind of research and development effort that private industry just will not and cannot take on. The expense is so great.

It is the prime example of where the Government of this country, in this case, NASA can do that kind of work and position American corporations to get the fruits of the research and development and move this country forward so it will be a world leader in that market area in the future.

In that light of that, could you explain to this Subcommittee why this program has once again been proposed for elimination?

Dr. **Fletcher**. Senator Gore, you are absolutely right. In the early days, as you probably remember, NASA took the lead in launching the first communications satellite, SYNCOM 4, which led to future satellites, and I guess the builder of that satellite now has 50 percent of the world's satellites in synchronous orbit.

Senator **Gore**. Excuse me for interrupting. I am going to let you proceed, but if this administration had been in power at the time NASA developed the first communications satellite, it never would have been done because they would have said that Cessna may have some plans for developing a brand new thing called a communications satellite, and we do not want to deprive them of the incentive to do it. There wouldn't be communications satellites.

Sorry to interject the editorial. Please proceed.

Dr. **Fletcher**. I think it was, for a while we were the leaders because of that initial effort. We had decided about, it must be five or six or seven years ago, to get back into the communications satellite business. We are still in it, by the way. We have a lot of technology going on at several places within NASA which addresses advance communications.

The ACTS was felt, two years ago, I guess, by the administration to be lower priority than our other science programs, and so it was at the bottom of the list and got cut off twice, I guess—twice in previous years.

This year they made a blanket decision, and that is all of the programs that they "Xed" out in fiscal year 1987, would automatically be "Xed" out in fiscal year 1988. So there was no appeal on that particular one. But your points are all well taken, this is a problem.

Senator **Gore**. I appreciate your response and I take it from your response that in deciphering the delicate language used, NASA agrees with the points that I have made and would be delighted if the Subcommittee found a way to revive that program.

I hope that we will be able to do that. I think it is just ridiculous and incredibly short-sighted to eliminate that program.

Now with my colleagues' indulgence, I would like to ask a couple of questions about quality control. You emphasize this in your opening statement, Dr. Fletcher, and I do appreciate that. I also appreciate the fact that you have added some funding and some personnel and have gotten a very competent and qualified person to come and take charge of this effort, and I commend you for all of that.

I do have some concerns, however. Let me begin with an effort to question this line item. In response to the Subcommittee's actions last year, you have broken out a separate line item, and as you mentioned it appears to have gone from $7.6 million in fiscal year 1986, to $16.2 million in fiscal year 1988. But, is it not true, and I would like a brief response if it is possible on this—is it not true that in the process of constructing this line item, you have created an apples-and-oranges type of problem, and actually a lot of the slots that are included in this $16.2 million figure were in other accounts and other categories in the fiscal year 1986 way of calculating the quality control effort?

Dr. Fletcher. I think that Mr. Newman ought to address that, but I don't believe there was any reprogramming of money from other programs. This is an honest figure. The $16 million includes a lot of studies, includes people, and so forth. But I would rather Tommy give you the details on that.

Senator Gore. I am not accusing you of dishonesty. I am just saying that the fiscal year 1986 figure, there wasn't such a line item at that time. I am informed that actually that does not—that some of the items in the 1988 thing are from other categories.

Mr. Newman. Senator Gore, there was about $7.6 million in fiscal year 1986 that was for the chief engineer. When we came in with that budget, we did carry that in Space Research and Technology. So the increase really is from about $7.6 million in fiscal year 1986, up to the $16.2 million.

Now there is also another augmentation which is in the engineering and technology base in the manned-flight program, and that is over and above that. Moreover, the civil service increase that Dr. Fletcher spoke of is funded from the Research and Program Management. So we have increases in all of those areas.

Senator Gore. Fine. I will pursue that in written questions, because there are some technicalities there. Basically, I accept your response.

The larger issue here is the distribution of the increase. It appears that over 75 percent of the increase goes to NASA headquarters, whereas much smaller increases, and in some cases decreases are parceled out to some of the centers. 1.5 percent of the increase to Marshall, for example, and an actual decrease to Kennedy, if I am not mistaken.

Could you deal with that problem?

Dr. Fletcher. Senator Gore, I think you are referring to the distribution of the $16 million, and those, of course, are not people. Those are studies, and a good many of the studies will be sponsored by George Rodney's office. I am sorry to say George had to leave, but we can supply for the record what those studies consist of.

[The following information was subsequently received for the record:]

The 1988 studies consist of the following areas:

Fiscal Year 1988—Safety, Reliability, Maintainability, and Quality Assurance

[Total Budget Amount—$16.2M]

Reliability, Maintainability, and Quality Assurance	$6.2M
Maintainability	400K
NDE	1,250K
Software Management/Assurance	1,380K
LSI-VLSI and Radiation Effects (CRRES/SpaceRad)	2,630K
Program Practices	1.9M
NAS/NAE Congressionally Mandated	300K
Engineering Standards	400K

Battery Technology Improvement Program	1,200K
Technical Assessment Program	4.0M
"PRACA"	1,000K
Special Problem Assessments	500K
Problem/Mishap Lessons Learned System Dev	350K
Systems Assurance Program—Audits	450K
Safety "Hotline"	TBD
Others TBD (office support contract, safety data base, etc.)	
Safety Program	4.0M
Safety Documentation—Update of manuals, etc	1,100K
System Safety Engineering	900K
Safety Lessons Learned	300K
NHB 8060 Update/Ignit. of Metals in Oxygen (Other smaller programs make up balance	600K

Dr. FLETCHER. The people, however, that I referred to earlier, the 200 civil servants and the 200 support contractors, are primarily at the centers. Very few of those 400 people are at headquarters, and that is where you want the quality control people.

Senator GORE. Will the increase result in more NASA quality controls inspectors in the field, and in the plants of the hardware manufacturers?

Dr. FLETCHER. Absolutely, Senator.

Mr. NEWMAN. This particular increase, however, is for studies. The increases in the Centers are funded in other portions of the budget. Those increases are real and are about the 400 total that Dr. Fletcher mentioned.

One other point, the way we carry the Center distribution in an item like this, is we wait until the determination is made as to which Center will actual do those various studies.

So a substantial portion of the amount that shows as Headquarters here, will in fact be done through the Centers.

Senator GORE. Fine. I will wrap up in just two minutes. The Chairman and Ranking Member have been very generous with the time, and I do appreciate that.

Last year, during a hearing on May 8th, I introduced into the record a chart reflecting a decline in quality control personnel, from 1970 to 1985. I would like to ask you if you could provide for the record of this hearing an update of those levels of employment distributed NASA facilities?

Dr. FLETCHER. We can do that, Senator Gore.

[The following information was subsequently received for the record:]

An update for the total safety, reliability, maintainability and quality assurance civil servant manpower for the Agency is as follows:

	1986	1987	1988
Headquarters	34	47	64
ARC	42	50	56
GSFC	140	155	156
JSC	160	185	185
KSC	271	282	308
LARC	51	56	58
LERC	89	93	93
MSFC	125	169	208

	1986	1987	1988
NSTL	7	9	10
Total	919	1,046	1,138

It would be misleading to make a direct comparison with the 505 (August 31, 1985) total that was used in the May 8 hearing and the 919 shown here for 1986. Although there are certainly some "apples and oranges" in the May 8 numbers, we believe they are mostly R&QA numbers. Our best estimate of the R&QA numbers for FY 86 was 527 (as compared to the 505).

We are in the early stages of our SRM&QA manpower/budget analysis and there are certainly inaccuracies in the above data. However, it represents our best understanding at this time. Our intent is to collect and analyze not only civil servant data, but also support contractor, DCAS, AFPRO, and prime contractor SRM&QA data. It will take two to four months to develop and understand the data with a high degree of confidence in its accuracy.

Senator GORE. Now, there is one line in the Fiscal Year 1987 budget that jumps out and that is the line for the Jet Propulsion Lab budget. It appears that quality control at JPL was reduced from $4 million to $2 million during the course of Fiscal Year 1987. Could you explain what the story is there?

Dr. FLETCHER. Mr. Myers will answer.

Mr. MYERS. The $2 million for JPL represents only the funding that the Headquarters SRM&QA, George Rodney's operation, puts out at JPL. JPL's normal quality control activities are within their general budget area.

Now specifically, those items put out by George Rodney's group to JPL dealt with some areas of software assurance. It was a process of how do we control the quality of software. That project was phasing down in this year, so it dropped down to $2 million.

Senator GORE. In closing, again, Dr. Fletcher, I appreciate the emphasis you are placing on this. I appreciate it greatly. I, of course, feel that more needs to be done and after receiving your detailed responses on these questions, I would like to consult with you and your staff and get a better understanding of where the constraints are and want to work constructively with you in continuing efforts to address this problem.

Thank you, very much, Mr. Chairman. Thank you for your indulgence.

Senator RIEGLE. Thank you, Senator Gore. Senator Pressler.

Senator PRESSLER. Thank you. I shall be fairly brief. I have a meeting with the Secretary of Agriculture at Noon, and being a Senator from South Dakota, interested in reelection, I am sure I will be on time for that meeting.

Let me say that I am very concerned about the relationship between NASA and DOD, and Mr. Chairman, I think it is something we need to look into in a very positive way. I get the feeling from listening to discussions about the Space Station international negotiations, that DOD's new interest, all of a sudden, without any advanced notice, has caused a problem.

In fact, the RFPs were supposed to be released today. Yet, they have been delayed. But I get a feeling in talking to you, and I am sure that witnesses here cannot say it, that we have a very big brother-little tiny brother relationship, and DOD has a role to play. But they appear to me to be very insensitive in giving notice, in taking other concerns into consideration, and in being cooperative. I just sense that over and over again in the private meetings I have had.

Mr. Chairman, I will talk to you about this; it may be wise for us to hold a hearing on that at some point. I don't want to rile up feathers where feathers are not to be ruffled, but let me ask the question——

Senator **Riegle**. Senator Pressler, if you will yield, I think you have raised a critical issue. It is one of great concern to me. We are going to go directly into the center of that issue.

We have a GAO audit underway to try to pin down precisely what the space activity is that goes on within the Department of Defense, but with respect to your point, we are going to understand that relationship from A to Z before we are finished. We will take it up here, and I appreciate very much your raising it today.

Senator **Pressler**. Well, in regard to that, could you state, Dr. Fletcher, what the current status of the Space Station international negotiations, and in particular the nature of DOD's new interest in the program? How did you learn about it?

Dr. **Fletcher**. Well, Senator Pressler, Mr. Myers has been heavily involved in that activity. But let me just say what ought to be said before we go much further. We recognize that there had been somewhat of a deterioration in relationship between DOD and NASA. I noticed it when I first returned. When Mr. Myers came back, he immediately said hey, we have to do something about this. He reestablished an Aeronautics and Astronautics Coordination Board, which is co-chaired by himself and the Under Secretary of Defense, Dick Godwin.

That turns out to be a first step, but there are a lot of other steps. There are pieces of the Department of Defense which are not under Dick Godwin, and the piece that concerns, or that got involved in the Space Station was the Under Secretary for Policy. They simply raised a number of questions. They have never asked to use the Space Station, by the way. They raised questions about our negotiations with the Europeans, and asked if we wouldn't mind delaying it.

The decision then was made to delay further discussions until they had said their piece. I think they have said their piece at this point.

Senator **Pressler**. So far as you know, DOD still says it has identified no requirements for its use of the Space Station.

Dr. **Fletcher**. That is correct, Senator Pressler. Now, if you don't mind, I would like Dale to give you a status report on what has been happening with those SIG-space discussions.

Senator **Pressler**. Yes, and tie into that how likely is it that any one of the international participants, particularly ESA or Japan, might choose to withdraw from the program based on DOD's new interest in the program?

Mr. **Myers**. We have always described to the Europeans and the Japanese that there would be the potential of use by DOD for research programs in the Space Station. The new interest on the part of DOD brought this action into a space interagency group meeting.

I have attended the meetings on that and we are resolving the issues that are involved, but it is taking time. It is delaying our continued negotiations with the Europeans on the subject.

I personally don't think that the Europeans or the Japanese would back away from the program because of the possible use of the Space Station for research programs by DOD. We are isolating areas where things could be done on a proprietary basis, by commercial people. We can do that kind of proprietary activity for DOD, also.

Senator PRESSLER. So, how likely is it that one of the international participants, either ESA or Japan, might choose to withdraw? I know you have told them that DOD might be involved. You do not think that will happen?

Mr. MYERS. That is my personal feeling. I really can't speak for the Europeans.

Senator PRESSLER. What is your personal feeling, Dr. Fletcher?

Dr. FLETCHER. Well, it sounds simple when you asked the question, but this is a very delicate negotiation. We have a European, ESA Group, that probably is 11 or 13 nations involved in that; and then we have Canada, which is another whole piece of the problem; and then we have Japan. I don't want to say with assurance that these negotiations are going to be easy.

I think what Mr. Myers is saying is that he doesn't think that the issue of the possible Department of Defense use some day of the Space Station is going to be the major factor in completing those negotiations. I agree with that statement.

Mr. MYERS. That is correct.

Senator PRESSLER. Mr. Chairman, I would like to submit additional questions for the record, and let me say that I think that this Committee should make it very clear to DOD that we expect them to give notice and to be very sensitive to the international negotiations, and not to be announcing something at the last minute—just popping it on NASA, the way it has been done.

I know these witnesses cannot say that, but it has been my observation that DOD has been insensitive to the larger concerns involved here.

Senator RIEGLE. Thank you, Senator Pressler. Let me just say, before calling on Senator Adams, that I am very pleased that Subcommittee participation has been so broad today, and the interest that has been shown is so keen.

I think it indicates that we can really carry out our responsibility to be good working partners with NASA. We have to be the ones, as you know, Dr. Fletcher, to go ask for the money. And we have to go to our colleagues, as you do, and to be able to present a convincing case as to what NASA intends to do, why it is important to the country, how, under our existing budget pressures, we can justify those kinds of level of expenditure, and that the money will go for the right things.

So the kind of careful and serious questioning that you have heard today I think is a measure of the seriousness with which this Subcommittee wants to carry out its side of that partnership.

Senator Adams.

Senator ADAMS. Thank you, Mr. Chairman. I want to state how pleased I am that you have moved ahead rapidly with oversight hearings on the entire program, and in particular, have moved the budget forward rapidly.

I have checked and I understand that the questions have been asked on Space Station budget and Heavy-Lift Vehicles. Therefore, I will not repeat any of those questions.

I have just one question, Dr. Fletcher.

First, as a preliminary statement, I am concerned that we are continuing at the present time to place most of our eggs in a Space Shuttle basket. I am very supportive of the Space Station, and I want to know whether we are planning—and this is my statement—to use various ELVs to carry materials and to move this program forward with the remaining three Challenger-type vehicles being used for the human force in space, so that we could move forward the Space Station, which is actually an interim step to moving into higher orbit, and to carry forward a really forward-looking space program.

It is my understanding, and this is my question, that the request for proposal for the Space Station has been delayed, and I would like to know whether this delay in the RFP is delaying the entire program schedule. In other words, I don't want the Space Station to be delayed indefinitely while we are working out Shuttle problems. It seems to me that we should be using expendable launch vehicle capacity and wherever else we can to move that program forward and not have this be a domino effect of waiting for the first domino to fall, which I think your testimony to this Committee previously indicates that it may be some time before we reactivate in full force the shuttle vehicles.

Dr. FLETCHER. Senator Adams, you asked an awful lot of questions.

Senator ADAMS. No, I just have the one question, the RFP. The rest of it, you might say, is my comment on where the program is. I will not ask you to comment on my comments.

Dr. FLETCHER. Let me address the RFP question. We really apologize for not releasing the RFPs on February 3rd when they were scheduled to be released. But it had do with the costing exercise that we went through.

We have a commitment to both OMB and to the Congress to make a thorough cost analysis of the Space Station configuration that we showed last year before we proceed.

We have to get our house in order in terms of these costs. We have at least two different cost estimates for the full program that have been developed in-house; one by the Program Office, and one by the Comptrollers.

Senator ADAMS. So it is being delayed because of the cost estimates, and not because you have slipped the whole program because it is sitting behind the correction to the Shuttle program?

Dr. FLETCHER. That is absolutely correct, Senator Adams.

Senator ADAMS. You are in the process—and I know these questions have been asked on the relationship of the other departments of the Government, particularly Department of Defense, developing sufficient lift to carry out other missions—you are not delaying the Space Station—I will ask it a different way.

Are you utilizing the capacity or the ability to build expendable launch vehicles which we know about, in conjunction with what we have left of the shuttle program, to move the Space Station forward? I am concerned that it may be delayed based upon correcting the Space Shuttle program.

Dr. FLETCHER. The Space Station delay, you correctly assumed, was due to the costing exercise that we are going through and in connection with looking at expendables to support the Space Station, assembling and so forth, we have made a very thorough look at existing expendables, and those that are likely to be around in the 1990 period, when we start assembling the Space Station.

What we have yet to do is address the question, if we had a Shuttle-Derived Vehicle, which is an advanced kind of an expendable launch vehicle, how would we use that to assemble and support the Space Station? Even though that question has not been answered thoroughly, that is not the reason for the delay of the RFPs.

The entire reason for the delay, and I hope it is not very long, is due to this costing exercise. There is a requirement, from Congress, that we actually give Congress our best estimate of the cost of the entire Space Station, and that is all that is required of us. But we felt obligated to look at other options in case the cost is much higher than we had previously assumed, which it is. How much higher, we have yet to——

Senator ADAMS. Do you have a date yet, Dr. Fletcher, for when you are going to do this?

Dr. FLETCHER. We have an internal date for which we can settle our own estimates of the costs, and that is soon, like two weeks from now. But this has to be reviewed by I don't know how many people. It depends on OMB and yourselves to be sure that it is all right. There remains the question of whether we are going to be allowed to release the RFPs with our own internal cost estimates. I think we should, but that discussion isn't settled yet.

Senator RIEGLE. Senator Adams, please continue. I know you have had other committees to have to attend this morning, but I want you to take whatever time you would like to to pursue this issue, or any others.

Senator ADAMS. Thank you, Mr. Chairman. I have pursued what I wanted, which is whether it was coming up and whether it was being delayed by the Shuttle program problems. Thank you, Mr. Chairman.

Senator RIEGLE. Thank you. I am going to cover a few items here. Most of the things I think have been worked pretty well, this morning.

The Congressional Budget Office has been asked to work up some budget options in terms of how the deficit gets squeezed down to meet these Graham-Rudman targets. The word is that two of the options that they are going to present with respect to the civilian space program and NASA are, one, the cancellation of the Space Station program, and, two, the cancellation of the funding for the Space Shuttle to replace the Challenger.

Now I mentioned that because the scale of the budget problem that we are facing is of such a dimension that for the Congressional Budget Office to frame up the options as to where we might make spending reductions to meet these legal deficit reduction targets, that these, in their judgment, are two items that might be sheared off with a major dollar saving that could impact the budget deficit.

Needless to say, from my vantage point, those are both critical to maintaining the forward thrust within NASA and to get ourselves squared for the future here. I not only want to bring that to your attention, but if you have a brief observation you want to make, feel free to do so.

Dr. **Fletcher**. Mr. Chairman, I would like to respond to that. I would like to say loud and clear, so that there is no mistake about it, that that would be a terrible mistake for this Nation to make; to cancel both of those programs. That is unthinkable in my judgment.

It is true we have budget deficits. It is true that we had an accident and we have to recover from that accident, but to ruin the Nation's Space Program because of a lack of funds for those two critically important programs, would be an awful mistake for this country.

Senator **Riegle**. It has been suggested on the House side, and if it hasn't, this will bring it to your attention, apparently there are some serious people on the House side, that given all the pressures on program tradeoffs and money, that some may propose that we not go ahead with the replacement Shuttle, and instead, divert that energy and money into ELVs on the theory that that is an alternative approach and one that perhaps we ought to consider. By ELVs, I mean of course the expendable launch vehicles, rather than the manned-additional Shuttle.

I do not know whether you have heard that talk developing, but it is clearly developing and I would like to give you an opportunity to make any early response to that idea.

Dr. **Fletcher**. Well, I would like to respond loud and clear. Admiral Truly was with me when we presented this same trade off to the President and his Cabinet. He said it much more eloquently than I can.

Admiral **Truly**. Senator Riegle, as you know, a great deal of last year was consumed in weighing the policy options for this country to return to space and have assured access to space, and as a result of that it did take a while and there was a lot of debate in this room and in the Administration. The decision was made to replace the Challenger.

It was made because every study that we made of required capability and of satellite backlog showed that not only did we need a mixed fleet and capability in expendables, which we, in NASA have supported the mixed fleet concept throughout this entire time, also that the first priority was to get the Shuttle system back in a viable condition.

I said that day, and I say again, that I personally think that a three-orbiter fleet is not a fleet. It doesn't have the reserve in it, once we get the discipline and operational capability back in the system, that is needed.

We have continued these studies after last year's work with a mixed fleet that Dr. Fletcher asked my office to conduct, and it is still in its final stages within the Agency, but again, it has shown that even with the fourth replacement orbiter, that we still need a mixed fleet as a NASA policy, and I think as a National policy. I have not seen anything that would change my mind.

Senator RIEGLE. Tell me what your latest estimate is for the completion and readiness of a fourth Shuttle, assuming we stay on track, as we now plan?

Admiral TRULY. As you know, the language in the appropriation made us wait to start construction of the orbiter in August of 1987, and we have yet to negotiate a contract with Rockwell International for the delivery. However, our best information, and our estimates and what we can learn from the contractor, predict the delivery of the orbiter I think in May of 1991. Therefore, the first flight would be at the latter part of 1991.

Senator RIEGLE. I take your response to mean that if we resolve our current problems that we are working on, and we are back safely flying with a three-orbiter fleet before the new replacement is produced, that even assuming that, a three-orbiter fleet is not sufficient to let us carry out what we see as the basic work that has to be done. Am I clear on that?

Admiral TRULY. That is my personal view. During the years from 1988, when we start flying again, until 1991, we will be building up the flight rate. We think we can get a flight rate with four orbiters, and with some enhancements and discipline within the system, to about 16 flights per year. But these interim years will be build-up years. Four flights, because we are starting late in the Fiscal Year 1988, then nine flights, then ten, and then 13, and then with the arrival of the fourth orbiter, up to 16.

If we can't make 16 because of flight safety, we will fly less than that, but nevertheless, even at that flight rate, in our projects of need, both in the civil space program and in the military, we need that fourth orbiter and we need a mixed fleet.

Senator RIEGLE. In a related point to that that has been very powerful in my mind, there are always risks in this program. We saw them in their most extreme form a year ago when we had this tragic accident, but if we were to go with a three-orbiter fleet and not build a replacement and, God forbid, something in the future would happen that we would lose another orbiter—which always can happen, no matter what safeguards we take, there is always some element of risk there—in my mind, it is seen that should that awful occurrence ever take place in that situation, if we are ever reduced to a two-orbiter fleet, for all practical purposes, it seems to me that really does sort of shut us down in terms of being able to function properly and to carry out anything like the scope of activity that we see having to be done.

I do not see anything else coming along that really fills that gap. Now, obviously expendable launch vehicles can do certain things for us, but for example, anything like the next technology option, the Space Plane, or something of that kind, is a long way off. So it seems to me, whether we like it or not, we have to make the Shuttle fleet very durable. We have to have enough of it so that we feel we can carry out our responsibilities and our plans with some measure of confidence.

So it is awfully hard for me to see how we could leave ourselves in a risk position of trying to go with a three-orbiter fleet, which you are prepared to say would not get the job done anyway, when, if you extend that over a long period of years, you have yourself in constant jeopardy, that any kind of accident or problem could basically take you right back out of the game for a long period of time.

It seems to me, those are the kinds of strategic risks we ought not to run. That is why I think we have to do a better job of planning and making commitments to see to it we do not find ourselves in that situation. Does that seem to square with your thinking, or Dr. Fletcher, with yours?

Dr. FLETCHER. Absolutely, Mr. Chairman. I will risk—I have always felt that five was a minimum, and I get slapped on the wrist by my boss every time I even mention that. But this is not the proper time or forum to talk about five.

But because of the reasons that you gave, a four-orbiter fleet makes sense. That is about the minimum size you could have. But if you have trouble with one of them, you are really in big trouble, even with the three that are remaining. I have to keep reminding you that the Free World has only one way of getting people to and from space and that is with the Space Shuttle, and that will be the case for some years to come. The Europeans are talking about maybe having their own manned system, but that is going to be way out.

Senator RIEGLE. At least a decade away, would you say?

Dr. FLETCHER. Oh, at least, yes. Probably beyond the turn of the century. We also have a National Aerospace Plane. But as you properly indicated, that, for operational use—an experimental plane may happen in the early 1990's the operational plane for our purposes is still way beyond the turn of the century. So the Shuttle remains our only way of getting people to and from space.

Senator RIEGLE. I think that is an important point. It is our workhorse and it has to remain our workhorse for a long period of time. It seems to me that we have to face realistically the front end investment question. I do not think we can fool ourselves here about thinking we can do too little and have that be sufficient.

But I think it is important that these issues get focused here now, because it sounds to me as if that debate may start to develop and we have to be prepared for it when it does.

I have a series of other questions, and I am just going to mention to you what they are. I may ask you to comment on one specifically.

In November of 1986, the Space and Earth Science Advisory Committee issued a report, "The Crisis in Space and Earth Sciences: A Time for New Commitment."

I am going to ask you some questions about that report, and I would like your response to those questions. I would like to know what your feeling is about it and how you are proposing within NASA to deal with some of those recommendations.

This relates to a question that was raised earlier by others, and that is, it was recently reported that 61 percent of the Office of Space Science and Applications Budget will go to industry in fiscal year 1987, compared to only 15.8 percent for universities.

I think we have to take a look at that in relationship to what it has been in, say, over the last ten years, and what it means if we are finding that a larger percentage of the Space Science money is going to industry and not to universities; it relates, I think, to the questions that others were raising, and that is, how do we draw more people into this area of work and interest, particularly on our university campuses across the country.

The one issue that I would ask you to comment on is this, I know that you are in the process of renegotiating with the Air Force your Launch Services Agreement. I am sure this is one of the more pleasant and enjoyable things you are dealing with these days. I want to understand the status of those negotiations.

I want to know, for example, has NASA agreed to provide nine Shuttle launches to the Air Force—not ten—for prior payments as a result of the agreement. If so, what was the amount of those prior payments?

I also want to know, are we going to be sharing—will NASA be sharing with the Air Force Shuttle and ELV launches for the cost of the hardware as a result of this agreement?

Bring us up to date on where this stands.

Dr. **Fletcher**. Senator Riegle, as you know, that has been a long and difficult process, but on the other hand, I think we are making progress. Earlier I mentioned that we have the Aeronautics and Astronautics Coordination Board with the Department of Defense. We have a similar relationship with the Air Force. Admiral Truly is the co-chairman of that group, and as such, he has been doing a lot of the negotiations under the aegis of Dr. Myers.

The status of those negotiations, I think, Admiral Truly can respond to and maybe even give you the final answer. I am not sure.

Senator **Riegle**. I noticed that Admiral Truly has a few more gray hairs than before he started that negotiation process with the Air Force.

Mr. **Myers**. Mr. Chairman, it is true that this has been an ongoing and somewhat difficult negotiation with the Air Force, but I am pleased to say that we have reached a verbal agreement, which we are now putting together in final form.

It goes as follows: We will pay for the hardware for the launch vehicles, and they will pay for the hardware for the Shuttle Program flights. We will pay for expendable launch vehicles one fiscal year prior to launch.

Now that turns out to be a very important thing in this issue of the expendable launch mixed fleet study that we have. It makes a major difference in the upfront funding problems that we will have there. We did, in fact, settle on nine flights that we would make available to DOD, as compared to the eight that we had calculated, and the ten that they had calculated.

The tradeoff to me was getting the opportunity to have a much more flexible planning base because of the agreements on one fiscal year ahead funding, rather than full hardware funding at the beginning of the progress payments for the industry.

I think that covers it.

Senator **Riegle**. Is the agreement firm now?

Mr. **Myers**. It is a handshake by me and Mr. Aldridge.

Senator **Riegle**. Is it being reduced to writing?

Mr. **Myers**. It is being reduced to writing now.

Senator **Riegle**. When do you think you will have that ready?

Admiral **Truly**. Some of my people are working with the Air Force people now. I haven't talked to them in the last two or three days, but we met with them as recently as a couple or three days ago. I am sure it will be within the next few weeks.

Senator RIEGLE. So the status is that an agreement has been reached on a handshake basis. It is being reduced to writing and within a matter of days you will have that document, assuming that both sides agree with what the printed words are on the pieces of paper. We will then have an opportunity to see that and to review it ourselves; is that right?

Mr. MYERS. Yes, that is correct, Mr. Chairman. There is one element that I think is still being worked on and one that Mr. Aldridge and I didn't quite understand ourselves. It has to do with the use of the Titan 34D on the pad that will be dropped by the Air Force and made available for commercial launch vehicles.

In that case, there will be some amortized costs that NASA would have to pay for any launch pad changes, or maintenance, associated with the launch of a 34D. The reason I mention that is that gets into the issue of the cost of a 34D for us, as compared to a Titan IV.

The Titan IV is the new, upgraded vehicle that is coming down the line for the military. The 34D is the one that at the present time looks like it would be less expensive for a launch of something like Mars Observer.

So that little piece is still being worked on, but we believe that that will be wrapped up in the next few weeks.

Senator RIEGLE. I look forward to the answer to the other questions for the record. I appreciate that response and we do want to see that document as soon as there is a copy available.

My colleagues will also be submitting questions for the record.

I want you also, if you will, to take back a message to everyone who works with you at NASA. That is, speaking for the American people and as well as for those of us in the Congress who are concerned with these issues, we appreciate all the effort that is being made. We appreciate the late hours and the long nights and the hard questions and the struggles that are going on here.

I know that it is frustrating for many people to find that in the aftermath of the accident, all the tragic personal consequences of that, but as well, the frustrations that come with trying to take and fix things and get going again, and what-have-you. I just want to tell you that the effort being made, hour by hour, day by day, by countless people who never will come to a hearing like this is appreciated.

I want to acknowledge it here today. I think the country is in the debt of the people who are doing that work and who, over a 25-year period in terms of a distinguished record for NASA, have produced outstanding results for our country.

We are going to get back into space and we are going to do it on a safe basis. That commitment I am convinced is clear across the board. We are going to find a way to provide the funds we need for a balanced program.

Now we have some issues to settle in terms of what that balance should look like. We have touched on many of those today. But it is very important that we be together on this, that we understand each other, that everything is out in the open, that it gets fully debated, looked at in the sunlight, and that we understand what it is we are setting out to do.

We cannot have a situation where we end up bending off in a direction that leaves the country or anybody else behind in terms of understanding what our goals are.

I think we are making good progress and I appreciate all the hard work. I know there are times when you probably wonder how you can respond to all the requests that you have to appear here, to appear there and to take all these steps.

For our part, speaking for this Subcommitte and this full Committee, and you saw an expression in the interest today, and you did again previously with our first hearing, that we are determined to do our part and to do it constructively, affirmatively and positively in working through these issues.

You can count on us to continue to carry our share of the load and we appreciate and know that you will be continuing to carry your share of the load.

So thank you, and we will see you here again, soon.

The Committee is in recess.

[Whereupon, at 12:25 p.m., the Subcommittee stood in recess.]

[The following information was subsequently received for the record:]

Responses to Written Questions Submitted by Senator Gore.

Dr. Fletcher, the Air Force recently submitted a FY 1987 supplemental request for research and technology development activities for a new heavy lift launch vehicle. Based on recent comments by Secretary Aldridge, it is quite clear that this is not a shuttle derived heavy lift launch vehicle.

Question 1: Could you please inform the Committee of what role, if any, NASA had in this decision? Why should any additional FY 1987 or FY 1988 funds be expended on the joint NASA/DOD Space Transportation Architecture Study if it is quite clear the Administration has already decided on future launch requirements -- the manned vehicle it appears will be the Aerospace plane and the unmanned vehicle it appears will be the new Air Force Heavy Lift Launch Vehicle unless NASA starts the development of alternatives?

Answer 1: NASA did not participate in the DOD decision to submit an FY 1987 supplemental request for research and technology development activities for a new heavy lift launch vehicle. Since the DOD announcement, a number of discussions between the Air Force, SDIO, and NASA have occurred with regard to the need for a national program to meet national requirements. NASA is reviewing our requirements and how we might effectively participate in a heavy lift launch vehicle development program.

Completion of the ongoing joint space transportation architecture studies is needed to prioritize the technology developments required for a heavy lift launch vehicle, a new manned vehicle, and a reusable orbit transfer stage. The joint architecture studies are defining the technologies that are needed for second generation manned vehicles using rocket propulsion, whereas the National Aero-space Plane Program is focused on airbreathing propulsion.

Question 2: Does NASA have any R&D funds in the FY 88 budget request for heavy lift launch vehicle R&D? Is the $5 million recently added to the FY 1987 Operating Plan Advanced Programs account the only HLV money in NASA?

Answer 2: NASA does not have any funds in the FY 1988 budget request directed specifically to the development of a heavy lift launch vehicle. Within the Advanced Programs area, NASA has requested funds to support continuation of studies and advanced development for future transportation systems including advanced liquid oxygen/hydrocarbon booster engine studies, advanced liquid oxygen/hydrogen engine studies, propulsion/avionics module studies, and advanced recovery system studies, all of which could be applicable to the development of a heavy lift launch vehicle as well as a second generation manned vehicle. In addition to these contractor studies, NASA is conducting in-house studies of Shuttle-derived launch vehicles and Shuttle II.

In addition to $5 million added recently to the FY 1987 Operating Plan for heavy lift, approximately $5.6 million in FY 1987 was already allocated to studies and advanced development for future transportation systems which could be applicable to a heavy lift launch vehicle.

Question 3: What is the current status of NASA's own internal study as to the utilization of heavy lift launch vehicles for the space station deployment and logistical support? In light of the fact that the Air Force has initiated a heavy lift program, will NASA now reconsider the use of ELVs for the space station?

What influence did the heavy up front costs required in development of a new heavy lift launch vehicle have on NASA's original decision not to utilize an HLV for the space station?

Answer 3: The Space Station program has baselined the Space Shuttle for both Space Station assembly and logistical support. This was done after detailed consideration of both existing ELV's as well as the new HLV's currently under discussion. The studies to date on the use of existing ELV's lead to the conclusion that their most reasonable application on the Space Station program would be the launch of the platforms. Their utility in reducing STS flights for assembly of the manned base is constrained to some extent by the need for the STS's manned capabilities on orbit to support assembly operations before the Permanent Manned Capability (PMC) is attained, and the need for the STS as a crew exchange vehicle after PMC. The Office of Space Flight and the Office of Space Station are continuing to study the use of a Shuttle-derived launch vehicle for Space Station support. The studies to date indicate that while the total number of launches required to assemble the Space Station can be reduced by utilizing a Shuttle-derived launch vehicle, it presents issues including potential Space Station redesign, concurrent development with considerable uncertainty in environmental requirements, and in more complex orbital operations early in station assembly. The agency is continuing to analyze the most optimum approach, including the use of a Shuttle-derived launch vehicle and/or existing ELV's for Station assembly and logistics.

Up-front development costs were only one factor in NASA's original decision not to utilize an HLV for the Space Station. Other factors included the schedule availability of a heavy lift launch vehicle, and increased on-orbit operational complexities during the early phases of Station assembly.

Question 4: Last May, at a hearing on the NASA Space Transportation System, this Committee was told that it would soon be provided with the preliminary report of the joint NASA/DOD Space Transportation Architecture Study -- the supposed basis of the recent DOD heavy lift launch vehicle decision. To date, this report has not arrived.

Could you please inform the Subcommittee as to when the preliminary STAS Report will be provided to the Subcommittee?

Answer 4: The Joint NASA/DOD study team completed a report for the National Security Council in May 1986, including an Executive Summary, a Study Overview, and Annexes. The Executive Summary was transmitted to the National Security Council in August 1986 after internal coordination within DOD and NASA. The Study Overview and Annexes were transmitted to the National Security Council in December 1986 after internal coordination within DOD and NASA. The study defined a reference architecture including an unmanned cargo vehicle for the mid-to-late 1990's, a new manned vehicle for the early 2000 timeframe, and a reusable orbit transfer stage for the late 90's. At this time, the National Security Council has not provided direction nor given permission to release the study report.

Responses to Written Questions Submitted by Senator Kerry.

Question 1: In light of the fact that this observer can be launched on the Shuttle or on a Titan III, could you elaborate on the specific reasons for the delay?

Answer 1: In view of the fact that the Shuttle manifest currently allows for only three planetary launch opportunities in the 1989-90 timeframe, a decision was made to slip Mars Observer to the next launch window in 1992 since it was in the earliest stages of development and would therefore be impacted the least by a launch delay.

Question 2: Also, is it true that the delay may add more than $100 million to the cost of the mission? Could you please elaborate on the cost increase with the program stretchout and what the principal cost drivers are?

Answer 2: It is anticipated that the increase to the total runout for the development program associated with the two year slip from 1990 to 1992 is about $90 to $100 million dollars. There are three main reasons, all of which are the result of the constrained Mars Observer budget. First, the spacecraft fixed price contract would have to be renegotiated for a later delivery which would result in a loss of the opportunity by the contractor to take advantage of larger equipment buys in common with other programs. Second, the period of performance for the government furnished equipment contracts which includes all of the scientific instrument contracts would have to be extended. Third, the project staff, key technical people and the scientific teams would all be extended for an additional period.

Responses to Written Questions Submitted by Senator Adams.

Question 1. Dr. Fletcher, could you describe the current relationship with our international partners in the Space Station program? What is the current status of the Space Station Life Sciences Laboratory? Will this be handled by the Europeans, or will it be in our module? Will the U.S. or ESA supply a centrifuge?

Answer 1: We are resuming bilateral negotiations with our international partners following the U.S. inter-agency review which was completed this month. A multilateral meeting was held on February 11 and 12, at which the Department of State briefed the partners on the revised intergovernmental agreement resulting from the interagency review.

Based on our studies to date, we have found that the concept of "functional allocation" in the Space Station laboratories is no longer necessary. As a result, a separate "life sciences laboratory" does not appear in the current baseline configuration. However, we recognize the importance of life sciences, and expect life sciences to be an important activity aboard the Station, conducted quite possibly in both the U.S. and European laboratories. In the Phase C/D RFP's, we will ask our contractors to insure proper accommodations for those life science activities that are compatible with the use of the microgravity laboratory. We also will ask the contractors to propose accommodations for those life science activities which are not compatible. With respect to the centrifuge, decisions on specific instruments have not been made yet.

Question 2. Dr. Fletcher, am I correct in the assumption that the alignment of work packages on the Space Station is now arranged satisfactorily and finally in your viewpoint?

Answer 2: The alignment of work packages is now satisfactory, having benefitted significantly from the review conducted last summer. While some adjustment to the work packages may be necessary in the future, I expect the basic framework of the Space Station work to remain as it is currently allocated among the NASA centers.

Question 3. Dr. Fletcher, would you describe how the Space Station will be used for satellite servicing and for transferring certain payloads such as communication satellites to higher orbits?

Answer 3: The Space Station servicing capability is comprised of a servicing facility, a telerobotic servicer, and a mobile servicing center.

The servicing facility provides for satellite servicing functions (refueling, repair, maintenance, and consumables replenishment) to be performed in an enclosed environment, utilizing telerobotics or crew extra vehicular activity (EVA).

The telerobotic servicer will be a highly sophisticated device, used for payload servicing at the Station as well as for remote payload servicing in conjunction with the orbital maneuvering vehicle (OMV).

The mobile servicing center (MSC), in addition to its role in assembling and maintaining the external portions of the Station, will also perform servicing functions for attached payloads. It will also play a role in the deployment and retrieval of satellites and other payloads delivered to the Station.

The Space Station is conceived--in the long run--as a staging facility for integrating payloads, such as communication satellites, with propulsion stages capable of transfer to geosynchronous orbits. This will include their checkout and deployment. Currently, the Space Station program has under study, as a possible growth capability, accommodations of an orbital transfer vehicle, (OTV). Such a vehicle could provide the capability for hauling large payloads, such as communication satellites to higher altitudes, i.e., geosynchronous orbits. It could also carry an OMV with it to use for precise positioning of the payload, and for docking the OTV at the Station.

Question 4. Dr. Fletcher, I believe that NASA has alluded to the fact that the Space Station may be used as staging base for lunar and solar system exploration, colonization and mining. Does the current Space Station design allow for these functions?

Answer 4: Yes, the Space Station has been designed to accommodate a variety of uses including future solar system exploration. The initial Space Station includes provisions (scars) for the addition of an Orbital Transfer Vehicle (OTV) that, when available, could be mated with payloads at the Space Station for the deployment of unmanned planetary probes. The Station is also adaptable to the accommodation of expendable launch vehicles if the OTV has not been developed when the planetary missions are ready for launch.

We have just completed an initial study of Space Station accommodation of a manned Mars mission. The results are applicable to manned Lunar missions since these are inherently less complex than manned Mars missions. The current Space Station configuration could accommodate the assembly, check-out, and other preparations for launch of a manned Mars vehicle with some modification. Additions to the Space Station infrastructure to support a manned Mars mission would include a quarantine module for the precursor Mars sample return mission, additional structure to serve as scaffolding for assembly of the Mars vehicle, and accommodations for a space based Orbital Maneuvering Vehicle and Orbital Transfer Vehicle. However, before any manned Mars mission could be conducted, new technologies would have to be developed. A Space Station would be required for these critical technologies. They include: orbital assembly and construction techniques, automation and robotics, techniques for handling and transfer of cryogenic fluids, closed environmental support systems, and research on the effects of long duration weightlessness.

Support of a large planetary effort, such as a manned Mars mission or frequent Lunar missions to establish a Lunar base, would require almost all of the initial Space Station resources. Therefore, major problems could be encountered in the accommodation of other missions on the Space Station.

QUESTIONS OF SENATOR PRESSLER AND THE ANSWERS

Mixed Fleet

Question 1a: Given a Shuttle flight rate that eventually reaches 12 to 16 per year, what is the expected shortfall in Shuttle capability, through 1995, vis-a-vis the anticipated payload and mission requirements for that same period?

Answer 1a: We are still evaluating the effects of a revised flight rate and the need for expendable launch vehicles. We are exploring options and approaches to accommodate any identified ELV requirements within the projections of the FY 1988 budgets. We will provide our plan to you, in the next several months.

Question 1b: How many of these are NASA payloads, and how many are DOD payloads?

Answer 1b: At this time an answer to that question is not available. The problem of how the "pain" of any shortfall in capacity would be allocated between NASA and the DOD has not been worked. However, in the early years of the 1988 to 1995 time period, recognizing the national security priority of the DOD payloads and that DOD ELV capacity is still building up to full capability, it is likely that NASA payloads would receive the majority of any shortfall hit in the near term. Beyond the near term the shortfall could vary significantly based on budget limitations and actual flight rate achieved.

Question 1c: What does this shortfall assume in terms of Space Station transportation requirements -- does this assume the use of ELVs for Space Station logistics and assembly? Does it assume the availability of a heavy-lift vehicle?

Answer 1c: Shortfall in shuttle capacity is not expected to affect Space Station transportation requirements.

NASA is looking at ELV's and HLLV in support of Space Station, but no decisions have been made. However, the HLLV holds promise for use during Space Station assembly and logistics, if the vehicle can support schedule and reliability needs for the program. We continue to examine ELV potential for possible use in support of the Space Station program for assembly and logistics.

Question 2a: What conclusions have you reached about the need to utilize ELVs to compensate for this shortfall in launch capability, and when do you expect to make a decision on this issue? How much of this launch capability shortfall are we capable of making up through the use of ELVs?

Answer 2a: When the final results of NASA's Mixed Fleet Study are available, NASA will determine the need for procurement of ELV's for critical NASA payloads which require launch through 1991. NASA is finalizing the plans for review with the responsible organizations within the Administration and Congress. In regard to the second part of your question, given the availability of funding, our preliminary results showed that the ELV capacity exists to meet the launch needs of all delayed payloads which are compatible with an ELV. Since, however, not all delayed payloads are ELV compatible, the entire shortfall cannot be relieved through the procurement of ELV's.

Question 2b: Although I recognize that there are many different combinations of ELV's that NASA could procure to close the gap on this shortfall, what is a "ballpark" range of number of vehicles and associated costs for developing a "mixed fleet" capability? What factors will determine any decision to procure ELV services and the specific mix of ELV's?

Answer 2b: We have assessed the near term opportunities to utilize ELV's to provide relief to this backlog of payloads considering the availability of ELV's and the ability of payloads to reconfigure for an ELV launch. We have identified six potential requirements through FY 1991, including two Titan III vehicles for TDRS-E, and Mars Observer; two Delta vehicles for ROSAT and EUVE; and two Titan IV vehicles for TDRS-F and a planetary backup. The procurement costs have yet to be definitized but are estimated to be $500 million to $870 million, depending on our ability to implement the proposed quid pro quo pricing agreement between the USAF and NASA. Because Delta and Titan production lines are currently producing vehicles, no non-recurring funding is required to develop a mixed fleet capability as implied by your question.

In regard to procurement factors, since the NASA mixed fleet study has identified valid candidates for ELV launch, the availability of funding remains the primary factor for procuring ELV services. Specific launch vehicle selection will be determined based on individual mission performance requirements, ELV cost and schedule.

Question 2c: What is the likelihood that NASA will request a FY 1987 supplemental appropriation or a FY 1988 budget amendment to pursue a "mixed fleet" capability, and what would be the likely magnitude of either request?

Answer 2c: We are finalizing our study on the use of ELV's for civilian needs and are examining options to accommodate any identified requirements for ELV's.

There are reports that DOD is increasingly concerned about the Shuttle performance, or lift capability, once the Shuttle resumes flight, and that, due to this concern, DOD may offload even more payloads from the Shuttle.

Question 3a: What is the expected Shuttle performance out of Cape Kennedy and the West Coast, and what still remains as the greatest uncertainties concerning the Shuttle performance?

Answer 3a:

ASCENT PERFORMANCE

- From KSC to 28.5°, 160 nmi (104 percent SSME)....50,000 LBS
- From WTR to low earth orbit (104 percent SSME)...41,000 LBS (with Filament Wound Case)
- Total reserves of 3,500 LBS held out to offset performance uncertainties and possible weight growth

LANDING WEIGHT CONSTRAINT

- o Landing weight presently limited to 51,000 LBS
- o Loads analysis will allow increase to 58,000 LBS (1988)

POTENTIAL IMPROVEMENT

- o 109 percent SSME increases performance by 5,000 LBS
- o ASRM increases performance by 7,200 to 10,000 LBS.

The final impact of performance of the Shuttle based on the Shuttle recovery activities will be identified as soon as practicable and we will provide our estimates as soon as they become available. We continue to work with DOD in planning of Shuttle payloads.

Question 3b: To what extent might this performance be inadequate to support DOD payloads that are currently manifested on the Shuttle?

Answer 3b: Launch Trajectories for two DOD payloads, the DSCS and the DSP, are currently being studied to determine ways to help assure adequate performance margins with delivery orbits equivalent to those which were planned prior to STS 51-L. Lower than the desired circular orbits were proposed by NASA. USAF prefers elliptical orbits which would require less spacecraft propellant to achieve final orbit. NASA and USAF Space Division are studying several elliptical orbits. Final performance capabilities will be made available in the very near future.

Space Station

Question 4a: What, in fact, has the most recent cost analysis revealed about the Space Station development cost? What are the major "drivers" in any cost growth beyond the $8 billion cost?

Answer 4a: As a result of recent analyses NASA is establishing a new Space Station schedule and cost profile. This is now under discussion within the Administration. NASA expects to review the material with Congress shortly.

NASA and the Administration have completed a thorough review of the Space Station cost estimates based on extensive information developed from a 21-month Phase B definition effort and a critical evaluation of the Space Station configuration. This effort indicates that the Revised Baseline Configuration would cost $12.2 billion in 1984 dollars. The major drivers in the new cost estimated are necessary items not included in the preliminary estimate; management and systems engineering and integration ($.7 billion in 1984 dollars); basic laboratory and technical support from NASA Centers ($1.5 billion in 1984 dollars); as well as increased program reserves ($2.0 billion in 1984 dollars).

Question 4b: Do you expect to receive a commitment from the White House and OMB for Space Station development costs beyond $8 billion?

Answer 4b: Yes, the Administration has accepted the Revised Baseline Configuration with development costs estimated to be $12.2 billion in FY 1984 dollars.

Question 4c: The FY 1988 Space Station request of $767 million is $288 million less than NASA requested of OMB. How and to what extend does this reduced FY 1988 request affect the program?

Answer 4c: Of the $767 million, $733 million is currently requested of Congress for development of the baseline Space Station. This compares to $1 billion which was the development portion of the $1055 million request to the Office of Management and Budget (OMB). The $1 billion estimate was developed in the FY 1987 budget cycle when contract award was anticipated in May of 1987 instead of the current plan for an award late in 1987. Additionally, our internal program cost review has led to the conclusion that the first Space Station element launch date would not occur until March 1994, and is consistent with the requested funding in the President's FY 1988 budget. The recent Administration decision allowing us to seek Congressional approval to proceed with our revised baseline retains the Administration commitment to the FY 1988 budget and the funding projections for development in FY 1989 and FY 1990 would not increase. The revised baseline provides for permanently manned operations by early 1996.

Question 5: If NASA had to "cap" development costs at $8 billion, what design and capability changes would have to be made to the present baseline design and capability?

Answer 5: Significant changes would have to be made to the Space Station program were development costs limited to $8 billion. Station capabilities would be constrained by low levels of power, limited technology development, few attachment points for external payloads and little capacity for growth. These capabilities would not result in a program that would maintain a position of leadership in space for the United States in the 1990's.

Question 6a: Does the baseline design and development cost accommodate a "lifeboat" for crew emergency rescue?

Answer 6a: The Space Station baseline configuration does not include but could accommodate a Crew Emergency Return Vehicle (CERV). Costs of a CERV capability are not presently included in program cost estimates.

Question 6b: What different systems are under consideration for a "lifeboat" capability, what rescue capability would each provide, and what are the costs associated with each?

Answer 6b: NASA intends to conduct a Phase B study of emergency crew return systems. This will include analysis of several systems and provide us with a reliable cost estimate. Specifically the analysis will help us determine the capabilities and costs of configurations that respond to a variety of possible emergency scenarios, ranging from delayed logistics resupply resulting from delay in Shuttle launch to life-threatening illness among the crew.

It is expected that the final study will contain a range of possible return vehicles showing their capabilities versus their cost. Interim reports indicate that the cost will be very much dependent on the number of re-entry Gs on the vehicle. Selection will not be made until all potential designs are thoroughly analyzed.

Question 6c: When will a decision be made on a "lifeboat" capability, and will the international participants make any input into this decision?

Answer 6c: A decision on Space Station crew emergency return vehicle systems will be made at the conclusion of the CERV Phase B study. This Phase B study is contingent upon appropriation of the request for FY 1988 Space Station funding. NASA anticipates running two parallel Phase B studies at a cost of about $4-5 million each. NASA anticipates releasing the RFP in July, with work beginning around October. Phase B studies should last around 6-9 months. At that time an informed CERV decision can be made by NASA. Although the views of the international partners will be solicited and reviewed, the final decision on CERV will be made by NASA.

Question 7a: What has NASA's latest review of annual operating costs for the Space Station revealed?

Answer 7a: A very preliminary estimate as a result of the recent internal program cost assessment is an annual operating cost of $800 million to $1.1 billion (in FY 1984 dollars). This estimate does not include the cost of services provided by other NASA organizations, such as transportation to and from orbit. This estimate will be modified as we further define and solidify our operations plans.

Question 7b: How will these annual operating costs be shared with the international participants?

Answer 7b: The proposal under discussion with our potential partners assigns to each partner, including the U.S., the cost associated with maintaining the functional performance of its hardware contribution to the Space Station complex. Most of the above costs are associated with maintaining the functional performance of our hardware, and thus would be borne by the U.S. However, the costs that are not identified with a particular partners' element, but support the Station as a whole, are to be shared among the partners. It is expected that the costs will be shared on the basis of partner allocations of utilization resources, thereby aligning the costs and benefits of participation.

Question 8: What is NASA's present position on using ELV's for Space Station logistics, or resupply, missions and for Space Station assembly?

Answer 8: The Space Station revised baseline configuration is designed around and dependent upon use of the STS for assembly and checkout. Expendable launch vehicles (ELV's) might well be used for Station logistics. We are developing an agency plan for civilian use of ELV's. We are also examining the potential for using a Heavy

Lift Vehicle (HLV). NASA is studying the HLV with the DOD as part of the joint NASA/DOD Space Transportation Architecture studies to be completed this year.

Question 9a: Has NASA determined specifically how it will use the Space Station once it achieves a "man-tended" capability (after about 5 Shuttle assembly flights) and once it achieves a "permanently-manned" capability (after about 10 to 12 Shuttle assembly flights)?

Answer 9a: Specific determination of how the U.S portion of the Space Station capability will be used cannot be made until individual payloads/instruments are formally "selected" or "approved" for flight on the Space Station. Further, the U.S. portion of the Space Station capability is likely to be shared by NASA, other government agencies, and U.S. private users such as industry.

During the "man-tended" period, it is likely that most, if not all, of the U.S. users will be funded by the government. The NASA Office of Space Science and Applications and Office of Aeronautics and Space Technology have made a preliminary identification of possible payloads which could beneficially operate with the capabilities provided by the Space Station during this phase. The payloads will primarily be attached payloads in the disciplines of astronomy, earth observations, plasma physics, and technology development. Activities within the pressurized module during this phase may focus upon checkout and verification of the module's systems and the early payloads. Extensive payload activity would follow this necessary preparation.

After the permanent manning of the Space Station, more ambitious attached payloads requiring crew participation for assembly, operating, or servicing are expected. The major addition, however, will be laboratory payloads primarily in the disciplines of materials research, fluid physics research, combustion research, and life sciences. At this time, it is anticipated that privately sponsored payloads, particularly in the area of materials research, will occupy a significant fraction of the U.S. portion of the Space Station. Payloads of these types are expected to require crew frequent crew attendance and may not be well suited to man-tended operation except for brief test runs that can be completed while the crew is present.

Question 9b: What scientific platforms and attached payloads will be operating initially, and what materials processing activities will occur?

Answer 9b: The Space Station program currently plans to launch the U.S. polar platform on the fifth launch of the revised baseline assembly sequence, although this launch may be moved in the near future. Early discussions on the use of this platform indicate a desire on the part of NASA, NOAA and our foreign partners to place into orbit a combination of operational and scientific instruments. These instruments will allow for research to be conducted in the disciplines of earth science, oceanography and weather. Specific instruments will be selected by the users at a later date.

Attached scientific payloads have been preliminarily identified by the Office of Space Science and Applications (OSSA). These payloads, which could begin to operate as early as the third launch in the Space Station assembly process, might include such items as the cosmic ray nuclei experiment, a large area modular array reflector and a cosmic dust collection experiment. Other payloads which could be made available include instruments for research in astrophysics, solar-terrestrial studies and plasma physics.

The laboratory module is now scheduled to be put into place on the sixth launch of the assembly sequence. On this flight the laboratory will be partially outfitted and a limited amount of experimental equipment will be in place. On the seventh flight, the entire capability of the Shuttle will be devoted to experimental equipment and the laboratory will be ready to receive equipment for specific experiments. OSSA has informed the Space Station office that it intends to do material processing work in the areas of biotechnology, metals and alloys, electronic materials, combustion, glasses and ceramics, and fluid dynamics. The specific experiments for early implementation have not yet been selected by OSSA, but their selection process is expected to begin in the near future.

The Office of Aeronautics and Space Technology has also preliminarily identified potential technological attached payloads that could begin operations early in the assembly sequence.

Mars Observer

Question 10: There has been some discussion about launching the Mars Observer on a Titan 3 ELV.

a. What are the costs associated with this option and could this option enable a 1990 launch?

b. What considerations are there - cost, scheduling, and otherwise - for launching the Mars Observer or one of the other planetary missions on a Titan IV ELV?

Answer 10a: Our current estimate of net costs for launching the Mars Observer Mission on a Titan 3 ELV is an increase of about $28 million. There would be an approximately $70 million savings on the spacecraft development by avoiding the two-year delay, which would roughly be offset by the cost of the Titan vehicle hardware that would be on the order of $74 million. There would, however, be an increase in cost as a result of the need to integrate the TOS upper stage with the Titan, which is estimated to cost about $24 million. It should be noted that costs would be increased in the near term (FY 1987 about $45 million and FY 1988 about $100 million) due to the schedule acceleration, the upper stage integration, and the vehicle cost.

b. A Titan IV will not be available to NASA to support a 1990 launch of the Mars Observer. When the Titan IV would be available to support any of the planetary missions and what its costs might be are uncertain because of the developmental nature of the program at this time.

Question 11: What is the current position on FY 1987 and FY 1988 funding for the Mars Observer? Do you intend to spend in FY 1987 all of the FY 1987 appropriated funds in order to preserve the option of a 1990 launch?

Answer 11: The funding for the Mars Observer in the FY 1988 budget request supports a launch in 1992. For the early part of FY 1987 NASA maintained the funding level to preserve the 1990 launch schedule while possible expendable launch vehicle options were examined. Recent overall budget assessment indicates that funding is not adequate to support the 1990 mission for Mars Observer and a decision has been made to adhere to the 1992 launch schedule consistent with the funding levels requested in the President's FY 1988 budget.

DOD's Shuttle Operations and Planning Complex

Question 12a: It is my understanding that DOD has recently decided to terminate development of its Shuttle Operations and Planning Complex at Colorado Springs.

How will this decision affect NASA's own mission control center at the Johnson Space Center?

Answer 12a: NASA made provisions to accommodate DOD Shuttle flights in the Mission Control Center (MCC) until the Shuttle Operations and Planning Complex (SOPC) became operational. With the SOPC cancellation NASA can continue to accommodate up to five secure flights per year at a security classification not higher than "secret." In addition, there are a number of highly trained DOD personnel who have been working at JSC in support of flight operations in preparation for the transfer of responsibility to SOPC.

The DOD has made a decision to reduce DOD manpower by 28 persons. These persons are highly trained key personnel who must be replaced by civil servants or contractors. It is expected that the affected persons will serve out their normal tours of duty, giving NASA time to train and qualify their replacements.

Question 12b: Will the present Mission Control Center be adequate once the Shuttle resumes flights and the Space Station is operational?

Answer 12b: While the MCC will be able to handle Station-related Shuttle flights, a Space Station Control Center will be required. NASA plans that it will be adjacent to the MCC. The ability of the MCC to support the STS flights may be constrained by the mix of secure DOD missions. This impact is now being evaluated in consideration of the DOD's cancellation of SOPC.

Question 12c: What enhancements might be required if this mission control center must support both NASA and DOD missions in the future?

Answer 12c: Reference answer 12a. In addition, the presently planned upgrade of the MCC, which offers significant productivity improvements of itself, will serve as a base to accommodate a variety of enhancements with relative ease and low additive cost. Moreover, the design is such that specific enhancements need not be committed to until the need is evident.

Question 13: Before the Challenger accident, there were 50 Shuttle flights dedicated to space science and applications in the seven years from 1986-1992. Now, with the new Shuttle manifest, only 17 Shuttle flights are devoted to space science and applications over that same period.

a. What are the implications over the next decade and beyond for such a sharp reduction in space science missions over this period?

b. What effect is this likely to have on the development and retention of space scientists at our universities and NASA?

Answer 13a: Clearly the number of Shuttle flights available for science and applications payloads will result in a substantially reduced rate of progress in research for the space sciences during this time frame. Most NASA space science missions will experience significant delays and over the next decade, flight opportunities for smaller missions will be significantly reduced.

b. The effect of the lower than expected flight rates on university space scientists will be felt in space research vitality well beyond the period on which flights begin to recover. Research groups that remain active will probably seek other, non-space related avenues to provide incentive and support. Also, training of the next generation of researchers (especially experimentalists) will be disrupted. A space research capability will survive, but the dynamism of the community would be expected to be below that projected prior to the Shuttle accident. An attempt will be made at maintaining active research in the space sciences over the flight hiatus with the implementation of the "Vitality Package" included in the FY 1988 President's Request. Moreover, while many flight programs are delayed, there remains a nucleus of exciting research missions over the next decade, albeit at a less-than-optimum level.

Advanced Communications Technology Satellite (ACTS) Program

Question 14: OMB has failed to include funding for ACTS in NASA's budget request, in spite of annual Congressional funding for the program and in spite of the fact that NASA has already exercised an option to purchase the upper stage for the spacecraft.

a. What funding in FY 1988 would NASA need to maintain a schedule of launch-readiness in 1990?

b. What inefficiencies, if any, have been introduced into the ACTS program due to the Administration's resistance to the ACTS program?

Answer 14a: NASA will require $84 million in FY 1988 to maintain the schedule for launch-readiness in 1990. This requirement is $14 million higher than the request submitted to OMB, which was based on a second quarter 1992 launch.

b: Development activities of the prime contractor (RCA) and its major subcontractors (TRW, Motorola, Comsat) have not ceased due to the proposed recissions. However, the uncertainties attendant to such proposals may not be conducive to optimum efficiency.

NASA AUTHORIZATIONS

THURSDAY, FEBRUARY 19, 1987

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met, pursuant to notice, at 2 p.m., in room SR-253, Russell Senate Office Building, Hon. Donald W. Riegle, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR RIEGLE

Senator RIEGLE. The committee will come to order. I welcome everyone today, and I want to indicate at the outset, before the committee starts, Dr. Edelson, that I want to express the appreciation of this subcommittee to you for your very fine work on behalf of the space science community. We are very sorry to hear that you are going to be leaving NASA before too long.

We want to wish you every success in your new undertakings and endeavors, and we hope that in the near future we are going to be launching many of the space science payloads that you were so instrumental in helping to identify and bring forward and which were developed under your leadership.

I guess if we have one regret it will be that when those launches occur—and we hope sooner rather than later—you will not be in NASA at that time. But you certainly will be thought of by many of us for your leadership getting up to the point where we are today and looking into the future.

So let me express that sentiment on behalf of the members of the subcommittee and the full committee.

Let me also say that we are meeting today to review the fiscal 1988 NASA budget request for the Office of Space Science and Applications. This is obviously a very important hearing since it is this office and its programs which have been most directly affected by the Challenger disaster and the current hold in all space operations.

In my view, the space science program, long our finest and most consistently productive NASA endeavor, is really struggling, and might be said to be only partly alive. We have not launched a planetary probe since 1977, now a decade, and we have no plans to launch another for at least two years, and of course even that timing I think is subject to change.

The latest report of the NASA Advisory Committee on Space Science has warned us that the United States may have lost its preeminence in space and earth science programs, a very worrisome observation. We will hear from that group today and will explore in depth their report on the current state of affairs in these programs as they would see it.

I have to say at the outset that I am troubled by the proposal to delay the launch of the Mars probe until 1992. I think this is a critical mission, in my view, and the delay would be a major blow to our space science efforts.

Finally, the proposed budget rescinds money from the Advanced Communication Technology Satellite program. This of course is the third time that that cancellation has been proposed, and each time the Congress has stated its belief that the program should continue.

It is a vital technology development program, with potential application and benefit to the United States. Yet the official position of the Administration is that it should be cancelled, in the face of clear and convincing evidence that Germany and Japan are moving rapidly to develop this very same technology.

I do not think that makes any sense. So we intend now taking a long and careful look at all the programs in the space science area.

The space science program is of great importance to the concept of a balanced space program, and I think we have got to maintain an active and vigorous program of exploration and development within this office in NASA, and I hope that we will succeed in doing that as we formulate the 1988 budget.

I will say one other thing, and this is an aside from our subject matter for today, and that is that a meeting has been called on an emergency basis of the members of the Banking Committee related to a major bill that will be taken up next week, relating to the insurance system for the savings and loan industry and various other matters of some urgency.

And unfortunately, that meeting was called for 2:30, and so at some point, as the ranking member of that committee, I will have to go and attend that meeting. And so at that time we will make some adjustments here in terms of who serves as chairman in my absence.

But we want to move on through this material today. Let me call on Senator Trible now.

OPENING STATEMENT BY SENATOR TRIBLE

Senator **Trible**. Mr. Chairman, thank you.

Let me just say, you do not have to be an astrophysicist or astronomer to recognize the importance of these programs to our past, to our present, and to our future. And so I look forward to the testimony of this panel and those that will follow, and look forward to shaping these programs with you and our colleagues on the committee.

I would add to that, Mr. Chairman, that the Foreign Relations Committee has a markup beginning in ten minutes on two arms control treaties. Senator Pressler I am sure is already there, and I will have to take leave of this subcommittee hearing and attend that session as well.

But I would say to the witnesses who will testify that, for the members who are present and for those unable to attend this hearing, we will review the testimony in detail, and we will benefit from your contribution.

I thank you.

Senator RIEGLE. Thank you, Senator Trible.

We are going to have that situation all day long today, because there are a number of committees meeting at the same time, as you know. But that is just the nature of what we face.

So with that, Dr. Edelson, let me have you proceed with your comments.

STATEMENT OF DR. BURTON EDELSON, ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS, NASA; ACCOMPANIED BY SAM KELLER, DEPUTY ASSOCIATE ADMINISTRATOR; DR. JEFFREY ROSENDHAL, ASSISTANT ASSOCIATE ADMINISTRATOR (SCIENCE); AND RONALD KONKEL, DIRECTOR, ADMINISTRATION AND RESOURCES MANAGEMENT DIVISION

Dr. EDELSON. Thank you very much, Mr. Chairman. I appreciate your very kind words. It is a pleasure to be here today to present the proposed fiscal year 1988 request for the space science and applications program.

I am accompanied here today by Mr. Sam Keller, my deputy, on the left; and on his left Dr. Jeffrey Rosendhal, our chief scientist; and on my right Mr. Ron Konkel, Director of Administration and Resources Management for Science and Applications.

With your permission, Mr. Chairman, I would like to submit my written statement for the record.

Senator RIEGLE. It will be printed in full in the record.

Dr. EDELSON. And show some material and describe very briefly our budget proposal, and then try to answer such questions as you may have.

For the past 28 years, Mr. Chairman, the space science and applications program has been a very vital and important part of our nation's space effort. It has made very significant contributions to our knowledge of the distant universe, of our cosmic neighborhood the solar system, and of our home planet, Earth.

And our program in applications has also reaped very practical benefits from space systems and space technology for life on Earth, in satellite communications, and weather satellites, in Earth resources assessment, and even in saving lives through our search and rescue satellite program.

I am confident that the outstanding tradition of excellence in space and in applications will continue in the future.

Last year, 1986, began as one of very great anticipation for us, Mr. Chairman. We called it "The Year of Space Science" to recognize the large number of important and exciting space science flight activities which we expected to come to fruition in that single year.

These included the Voyager encounter with Uranus in January, two important planetary missions, the Galileo and Ulysses, two major spacelab missions, ASTRO and ATLAS. Finally, we planned to launch the Hubble Space Telescope, the centerpiece of our space science program, in October of 1986.

Of this ambitious and exciting array of missions, I am sorry to say, only the Voyager encounter with Uranus became a reality in 1986. The loss of the Challenger, the extended two year down time in launches, and the termination of the shuttle Centaur program have had a severe impact and have required a massive replanning of our entire space science and applications program.

I will address the impact of the accident in a moment, but first I would like to take a bit of pleasure on my part to present two very important highlights that did occur in 1986, the Voyager encounter with Uranus and the Comet Halley activities.

In fact, I brought along a few viewgraphs just to give a little reality to it.

Senator RIEGLE. Very good. Would you like the ceiling lights turned off here so that this illuminates better, or what is your wish?

Dr. EDELSON. I believe we can see them pretty well the way they are.

Senator RIEGLE. Let us turn some of them off.

Dr. EDELSON. On January 24, 1986, the Voyager 2 spacecraft, after a flight of eight and a half years from mid-1977 to early 1986, made a remarkable encounter with the planet Uranus, nearly three billion kilometers from our own planet.

Our closeup observations of the planet and measurements revealed it to be even more mysterious than we had expected, with this blue-green atmosphere and striations and layering in the atmosphere. The Voyager photographed the nine known rings for the first time and discovered two more rings.

This next image, of the smallest of the five moons, a composite of seven photographs of the moon Miranda, surprised us with much more extensive and varied geological activity than we ever expected. It shows a very complex and totally unique surface.

It shows a patchwork of different grains, including huge icy canyons more than ten kilometers deep. The analysis of the data returned from Uranus will allow us to better understand this very unique world three billion kilometers away and how it relates to planet Earth and the rest of the solar system.

The Voyager 2 spacecraft now is proceeding toward an encounter with our most distant planet, Neptune, where it will arrive in August 1989.

Comet Halley, the second highlight of the past year, following a 76-year cycle, returned to the inner solar system in 1986. For the very first time in its 30 recorded appearances in history, Halley was tracked, observed, measured electronically, and even approached by a very sophisticated set of instruments on the ground, in Earth orbit, and in deep space.

An international flotilla of spacecraft from Europe, the Soviet Union, Japan, and the United States observed, and some flew by, the comet in space. On the ground, a thousand scientific teams from 50 nations participated in the International Halley Watch.

The very close approach, only 600 kilometers, of the European Giotto spacecraft to the comet's nucleus was made possible by the United States deep space net tracking and targeting the two Russian spacecraft, the Vegas, which preceded the Giotto by only a few days. That was known as—that tracking and targeting operation was known as Project Pathfinder and is demonstrated here.

A very significant contribution was the maneuvering and observation of the International Cometary Explorer, ICE, for a close encounter with the Comet Giacobini-Zinner in September 1985, followed by distant observations of Comet Halley in March 1986.

This very complex celestial billiard ball arrangement which is shown here involving five separate passes around the Earth and around the moon allowed us to retarget a space plasma physics experiment, turn it into a cometary explorer, and send it on its way right straight through the tail of the Comet Giacobini-Zinner to produce a great deal of scientific information and, from then on, to make distant observations of the Comet Halley.

The apparition of the Comet Halley really was a worldwide event and, in addition to the tremendous engineering accomplishment of getting the spacecraft there and the scientific results that we obtained and are still evaluating, it was a triumph of international cooperation and shows what peaceful scientific cooperation among nations can do.

The impact of the *Challenger* accident, as I mentioned, on our space science and applications program was substantial. We really have had to replan our flight program all over again. Originally, we had 50 space shuttle missions planned for science and applications during the years 1986 through 1992.

Of the 50, only 17 remain in those years in the new manifests. We have lost 33 during those years. This required stretch-out of our surviving missions by an average of something more than three years. Most of our planned missions have slipped past 1992 into the 1993 to 1995 time frame.

Some that appear to be slipping past that, unfortunately, we have had to cancel. Those were some spacelab missions. We are now participating in agency studies aimed at possible use of expendable launch vehicles to launch some of our free flyers.

Our planetary program has been very adversely affected, and we are reviewing it intensively to make the best use of available flights. Concurrently, we are working extremely hard to maintain the health of our scientific program. Our strategy to maintain momentum during the flight hiatus includes what we refer to as our science vitality package.

This is an infusion of funds to support various scientific activities in various disciplines, particularly in the university research community. It should, not incidentally, enhance the attractiveness of space sciences to students to present a viable research option during the hiatus of our space flight opportunities.

The vitality package will support continued basic research, data analysis from previous flight missions, and it will give increased attention to the suborbital programs—rockets, balloons, aircraft flights—as a source of near-term and continuing flight opportunities. The vitality package will provide some immediate relief, but these funds do not initiate major long term programs or obligations.

Although there is certainly no way, Mr. Chairman, that I can paint a happy face on the present situation in space science and applications, I can say that we have developed a reasonable plan to carry us through the flight hiatus and to put us in a strong position to conduct first class science missions upon the resumption of flight.

Now, I would like to briefly address the budget itself. As shown in this viewgraph, the total R&D request for the Office of Space Science and Applications is $1,508,300,000. This funding will support a balanced program in the various disciplines and will also fund the vitality package I mentioned, which is so needed to sustain a healthy research base through the flight hiatus.

The budget provides funding for one proposed exciting and important new start, which we have called the Global Geospace Science (GGS) program. This will provide full United States participation in a grand new international program, ISTP, the International Solar Terrestrial Physics program, which involves a cooperative effort with the European Space Agency, ESA, and the Japanese Institute of Space and Aeronautical Sciences, ISAS.

Two new United States spacecraft, termed Wind and Polar, will combine with the Japanese Geotail spacecraft and the European SOHO and CLUSTER missions to enable the first comprehensive multi-point study of global magnetospheric response to the solar wind.

GGS will provide a major advance in our understanding of solar terrestrial science and will assure a key role for the United States in this important field of international science.

Back to the budget, our fiscal 1988 budget will support the maintenance, testing, and certification of our centerpiece program, the Hubble Space Telescope. It will support the Galileo mission to Jupiter, the Ulysses mission over the poles of the sun.

The request will continue the development of several other very important flight programs, including the Gamma Ray Observatory, Upper Atmosphere Research Satellite, the Magellan, (Venus radar mapper mission), the Mars Observer, and the ocean topography experiment, TOPEX.

It will support critical activities in the life sciences and additional effort in the microgravity science and applications discipline. The budget will also support the continuation of the productive Explorer program and the activities necessary to maintain readiness of the spacelab and other space shuttle payload missions when flight resumes.

It will also support our development work on instruments and facilities for early use of the space station and will provide funds to implement the vitality package. Of our total of $1.508 billion, we expect that about $215 million will go to university research.

Two issues I would like to mention. Consistent with Administration policy, we are not requesting fiscal year 1988 funds for the Advanced Communication Technology Satellite, ACTS. Also, we have not provided funding in this budget to keep the Mars Observer on a development schedule for a 1990 launch.

We are currently studying the possibility of launching the Mars Observer on a Titan III expendable launch vehicle in August of 1990. We hope we will be able to work out both the launch and the funding problems to keep the Mars Observer on schedule. However, if unsuccessful, we must delay it because of celestial mechanics and launch windows until September of 1992.

Mr. Chairman, in conclusion the fiscal 1988 budget request for space science and applications will sustain a strong program once the shuttle starts flying again. It will ensure our readiness to implement approved flight projects as soon as practically possible.

I would like to conclude on a personal note, Mr. Chairman. As you know and as you have kindly remarked at the beginning, I have announced that I will be departing NASA later this spring. In my five years as Associate Administrator for Space Science and Applications, I have had the pleasure of serving with a really outstanding group of people within NASA and in our allied industrial and university communities.

I am very proud to have been able to play a part in the advancement of our nation's space effort. I would also like to thank you, Mr. Chairman and members of the committee, for your personal interest and support over the past few months particularly and in general during my tour at NASA.

Thank you very much.

Senator RIEGLE. Thank you. Let me make a couple of other observations here before beginning the question period. There is a lot of good news in terms of what is going on in our space efforts at the present time. I think the team at NASA, what is left of the old team and the members of the new team, are hard at work.

And based on what I am able to see, I think we are making progress. Now, obviously we are doing it within very difficult constraints, budget constraints, the fact that the shuttle is shut down for a length of time, and some other things.

But there is a lot of important work going on and it needs to be acknowledged.

The other day at the University of Michigan we dedicated a new space physics laboratory there that is really one of the finest facilities of its kind that exists anywhere. And I must tell you, in meeting and talking with the people there who have been so actively involved in space science work over many years, many successful projects, projects in the works now, that they are—hard at work, enthusiastic, and optimistic about what we could do in the future.

They are concerned about these constraints that we are working against. But I can tell you that from the time that I spent with the professionals out there, they are determined to get their part of the job done and they are getting it done.

And I am very proud of the fact that they are, and there are many others just like them around the country in terms of the American effort. And I want to say to all of those people out there by means of this hearing that we are appreciative of that national work. It has important strategic value to our country now and in the future, both in understanding weather patterns and things about our planet that we want to know otherwise, but as well beginning to understand what is out on this next great frontier, the frontier of space.

And so there is a lot of important work going forward, despite the difficulties that we have had this last year. And I think it is important that that be fully acknowledged. So I can just tell you from our people at the University of Michigan who are engaged in these things, they are moving ahead as rapidly as they can on every front, and we intend from our state to play our full part.

Dr. EDELSON. You can be very proud, Mr. Chairman, of the group that you do have at the University of Michigan, Dr. Donahue and Dr. Nagy and others. And as a native of East Lansing, I have often admired the tremendous scientific excellence that you have there.

Senator RIEGLE. Thank you. I do not know if Senator Rockefeller has any opening comment he would like to make at this point or not. He will make his comments as he goes along here. In short order I will have to excuse myself for a short time.

Let us start in on some of the substance here, and that is in your opening statement there were three items that you really did not highlight that I had perhaps expected that you would. One is the need for NASA to begin to procure expendable launch vehicles for space science payloads.

The second would be the need to identify a major space science mission for the future, such as the suggestion of a joint U.S./Soviet trip to Mars, a manned trip to Mars and back.

The third is the need to either provide more money for space science or admit that we are not going to be able to do everything that we are planning within the available resources.

I would like you to comment on each of those points, and then I will have a follow-up to that. Why not start down through those?

Dr. EDELSON. I will address points one and three, and I would like Mr. Keller to talk about the second one.

First, I did mention in my opening statement that we were interested in the use of expendable launch vehicles. We have studied and intensively surveyed our own missions and then worked together with Admiral Truly and his group to determine from a technical engineering point of view, first, and then from a cost point of view what we would possibly be able to do with regard to launching our science and applications free flyers on the expendable launch vehicles.

We have identified seven missions that are rather clear candidates for launching on expendable launch vehicles as a part of the overall study. Now, the entire study which has been done by Admiral Truly is still under review so that all the details have not been released, but I understand that the present status of the study has been briefed around town, and members of the subcommittee staff have cognizance of what is in it.

The report shows that using the Shuttle, even with the most optimistic assumptions with regard to starting on time and launch rate of 16 launches per year and the most optimistic view of using expendable launch vehicles, we cannot meet all of our launch requirements for not only NASA science and applications but other NASA missions, for Department of Defense missions, for foreign missions and other unique missions.

So it is usually understood that to some extent if we are to meet the requirements, we must use expendable launch vehicles. We have not solved the funding problem, and it is not clear to what extent several of the expendable launch vehicles will be available in certain time frames. That is under continuing review.

Senator RIEGLE. On that very point, let me ask you a question, and I am not asking you for a policy answer. I am asking you for a professional judgment.

We have our activity in the space area going on in the Defense Department. We have it going on in NASA. Some of it cross-relates, and some of it does not. We face the basic expendable launch vehicle issue in terms of how much of that capacity we need to have for the United States now to augment the Shuttle once the Shuttle returns to service.

I am wondering if it would make some sense for us, rather than to have two parallel operations, one in the defense area and one in NASA, in terms of expendable launch vehicles if we should not think about some way to consolidate that effort into one operation. There obviously would seem to be some dollar savings if you can avoid parallel operations, but it seems to me that we probably ought to think in some unified way as to what our expendable launch vehicle posture is going to be and our strategy is going to be for the future to accommodate whatever mix of needs, scientific, military, maybe commercial.

What would you think of that as a way to start to collect that issue in a tighter way so that we can work our way through it, given all these budget pressures we have?

Dr. EDELSON. It is very obviously an advantage in economies of scale and in cost effectiveness and interoperability of hardware to have very closely coordinated programs, and NASA and DoD have worked together for a very long time to coordinate our programs. We will, for example, make use of the MLV Deltas, and the DoD has used the Shuttle extensively, and we will continue in that coordination.

Whether any greater degree of consolidation, which is the word that you used, is required would be more of an organizational answer than it would a technical answer. As a program manager, as an engineer and as one who worries about costs and budgets, I can say that the closer the programs are coordinated in terms of interoperability and availability of resources back and forth the more effective it will be for both agencies and for the U.S. taxpayer.

Senator RIEGLE. Let me ask you this. From your vantage point, if I were to ask you if you feel you clearly understand America's ELV strategy, say, over the next five years as a nation, taking all of our requirements into account, do you have a clear sense of what our strategy is in that area? I mean, are you comfortable with the sense you have, or do we have a lot of work to do to really shape that out and get that sorted out more clearly?

Dr. EDELSON. I am uncomfortable with the situation, Mr. Chairman. I think everybody is. We have not completed any of the studies that we are involved in, and the studies themselves take an interminably long time because of their complexity and the various positions of the U.S. government agencies.

I think that it is a subject that is going to require a great deal of attention over the next few months before any of us are going to be comfortable with it.

Senator RIEGLE. All right, I have taken you off the track on that. Let us go back to the other two points that you were about to respond to.

Dr. EDELSON. Well, your second question has to do with a possible Mars mission, and I would like to ask Mr. Keller to address that since he has been involved in some of the studies and discussions.

Mr. KELLER. Mr. Chairman, I had the privilege earlier today to appear with Mr. Carl Sagan before the Congressional Space Caucus, and that was the issue we were discussing.

Senator RIEGLE. We will hear from him later today in this subcommittee.

Mr. KELLER. I understand that is the case, sir.

One of the things that Jim Fletcher has started under way in his new role as Administrator for the second time with NASA has been the study of future options and opportunities that we might indulge in. He has brought Dr. Sally Ride, the astronaut, in from JSC, and she has been working at headquarters and directing activity in the last several months which has included that as one of the options.

Now, we are not at this time in a position to come forward with what the future particular big initiative should be; however, we within OSSA have been for some time aware of the fact that a Mars manned mission is certainly a distinct possibility, and we have a number of activities under way which are consistent with future decisions that could go that way.

As I pointed out earlier today, a mission of that nature is very long. It is complex, it is expensive, and it clearly will require a national commitment to take on. An activity such as we had earlier today led to that. Our activities are of a number of types.

First of all, we are doing advanced technology development to respond to a number of things which we are not now capable of doing, certainly robotics and automation, improved power systems, things of this nature which would enable a mission like that to take place if the administration and the Congress should decide to do it.

We have under way a number of studies recently prepared in the last year or two by our Solar System Exploration Committee which recommend the precursor missions that will be necessary in a program that is clearly in the nature of 16 to 20 years before you actually take a crew to Mars and bring it back. We would have to go with surveillance missions. We would follow these with probably some kind of an automated sample return mission, unmanned. We likely then would fly by the planet and come back without landing. Finally, we have the manned mission.

A major, major concern is the ability of man to survive in essentially a zero G environment for a period in excess of two years.

Senator RIEGLE. That is the time that you anticipate for a round trip?

Mr. KELLER. It will probably take two years plus, depending on the scenario and the orbit, the amount of energy you have. It is certainly longer than anything we have done. The U.S. experience in Skylab is 84 days in microgravity. The Soviets are in the order of less than a year, so we do not have, first of all, bare data for all of it, and there is a question as to how good it all is.

So we have to conduct the major activity in the life science area to understand the effect on the human. We have to be able to provide health services during this period of time. We have to protect him from the effects of zero G. We have to provide the psychological understanding of what happens to people who live in a tin can for two years, and we have to understand the ecological systems that will support man in this environment for an extended period of time. Fortuitously, we are going to the Deputy Administrator tomorrow with a review of that program.

So we do have under way a number of activities which are consistent with the decision which the Congress and the executive may elect to make in the future. We believe the activities are supportive and provide that option, although we have not proposed anything today.

Senator RIEGLE. I find that to be exciting testimony in terms of the fact that you are doing that kind of careful assessment and that you are going forward, with a report of the examination of that question.

Do you have anything in the nature of ball park cost figures that you are even talking about or writing on the back of an envelope that it might cost us to go and do that over a 20-year time frame?

Mr. KELLER. No, sir, I do not. We have not costed that program out, but if I may say so, Dr. Sagan has an estimate, and I am sure that when he is on he will be glad to tell you.

Senator RIEGLE. Very good. We will come back to that in a bit.

I am going to have you, Dr. Edelson, if you would, respond to that third point. I have to excuse myself briefly, and I will be back just as soon as I can come back. Senator Rockefeller will be in charge of the committee.

Dr. EDELSON. Senator Rockefeller, the Chairman has tempted me considerably by his third question which asks whether having more money in the science program would be desirable or helpful. The answer to that is definitely yes. I will try to give you a reasonable answer to it.

Our program has suffered in delays, as I have mentioned, because of the *Challenger* impact, but we also suffer from the point of view of cost in real dollars because of the delay. As an example, the cost to keep the Hubble Space Telescope on the ground tested and exercised is about $7 million a month. We have a number of such projects which are delayed, and all that is reasonably expensive.

We have tried to make estimates of how much the total is, and we do not have any way of measuring it exactly, but it is more than $1 billion over the next five years. It is costing us that which we would not have to pay for if we had kept with the original Shuttle manifest.

As a part of NASA, we are obliged to swallow that additional cost within our budget, and our budget for space science and applications is flat for the three years which we are now considering, 1986 as most recently passed, 1987 the year we are in, and 1988, the year we are addressing today. We do have a flat budget, whereas the total NASA budget has grown.

We are frequently asked are we getting our share of the NASA budget, and the answer is I think that we are getting a fair share, but the numbers show that as a percentage of the total NASA budget the figures for those three years, 1986 through 1988, are 19 percent, 18.4 percent and 16.6 percent. So we are actually getting a lower share as the total NASA reseach and development budget, which is frequently quoted, those figures also go down from 23.5 percent to 19.6 percent.

So in general we are required to pay for a delay in the program out of a flat budget, whereas the total is growing, so I must conclude that it would be reasonable for us, and if we were able to get on with the major, new, exciting missions that are part of our plan, such as the Comet Rendezvous mission and the X-ray Telescope, increased level of funding for the space science and applications program is required.

Senator ROCKEFELLER [presiding]. Dr. Edelson, I thank you. Senator Bentsen from Texas has just arrived. He has been on a marathon Finance Committee trade chairmanship all morning and part of the afternoon.

Senator Bentsen, do you have a statement that you would like to make?

Senator BENTSEN. Mr. Chairman, not a statement, but when the questioning time comes, I would like to ask some questions.

Senator ROCKEFELLER. Very good.

The matter of the materials processing in microgravity and the Advanced Communications Technology Satellite gets at the area of what we are going to do in this country to become more competitive. You have within your budget the potential for microgravity research and biotechnology and crystal growth, ceramics, electronic materials, fluid dynamics. All of these things have potential applications for our industrial future, quite apart from our space future.

It has always been one of my worries, not just because of the Challenger disaster but because of the pressure of money, Gramm-Rudman and the rest of it, that those things which came out of the space program that did not directly relate to the military or to space but could have very strong application to our industrial future, our competitive future, would be shortchanged.

Now, I agree with you. You are talking about a flat budget, and, therefore, you are going over three years from 19 percent down to 16 percent in science spending. That still can be a lot of money, if you take ceramics, biotechnology, crystals growth, some of those areas, that are possible or already proven aids to our country's ability to compete on an industrial or commercial basis.

Dr. EDELSON. The area that you identify, Senator Rockefeller, which in the budget is called materials processing in space and which we term microgravity science and applications to give a better description of all the work that we are doing in that, is an area which we can identify as one which is very important to develop the science, the chemistry, the physics, metallurgical and crystallographic processes and the way they behave in low gravity environment.

Further, there are very good possibilities that much of that scientific knowledge of materials and of fluid physics and so on will result in useful benefits. I have heard the phrase factories in space and so on, which worries me a little because it is not likely that we will ever have anything resembling large production in space, but there is a good possibility that we can grow larger, finer single crystals from silicon or gallium arsenide, for example, to get what is know as wafer size crystals that would be improved over anything we could grow on Earth or that we could develop pharmaceuticals through advanced processes like electrophoresis in space.

Even more likely is that the knowledge that we get of the behavior of materials in a low gravity environment will give us knowledge of how better materials, material processing like diffusion and welding and so on, would be applied in production on the ground.

I have asked Katie Schmoll, who is responsible for our microgravity science and application program, to join me to add additional remarks to what I might have neglected.

Ms. **Schmoll**. Senator Rockefeller, all of Dr. Edelson's points are correct. I think one thing that I could give you an example of something that we would do in space, that we are doing in space, that has very clear industrial applicability on the ground, and that is our protein crystal growth activity.

The problem with protein crystal growth on the ground is that proteins are very delicate in their crystalline form. In order to get ready to do drug design, a very accurate drug design, it is important to have an understanding of the macromolecular structure of proteins and, therefore, of their active sites. About two years ago I began a flight program in protein crystal growth. We have since flown that experiment four times. It is a very small, very compact, very, essentially, easy experiment to run. We have gotten interesting results.

We have not had the opportunity because of the accident, unfortunately, to pursue those results in further experiments, but the results have been interesting enough that we now have six pharmaceutical companies participating in the program at their own expense, sending their researchers to work with our principal investigator at the University of Alabama at Birmingham and also providing materials for the protein crystal growth. Those materials are very expensive.

Senator **Rockefeller**. That is cancer related?

Ms. **Schmoll**. It certainly has that potential, sir. One of the areas that we are doing work on, in fact, is interferon, which clearly has cancer potential.

Senator **Rockefeller**. Is it an exaggeration to say that a portion of the cure for cancer could be up there?

Ms. **Schmoll**. It is not an exaggeration, sir, but I think it is very important to understand that it is a piece of the puzzle, and the piece is getting into a position where we can produce an interferon crystal, understand it, and understand how it works. That piece is possible in space.

Senator **Rockefeller**. Let me ask Senator Bentsen if he has some questions he would like to ask.

Senator **Bentsen**. Thank you very much, Senator. As you know, I have other commitments.

I would like to speak to you, Dr. Edelson, for just a minute on a question brought up with Dr. Fletcher a couple of weeks ago. Last year I introduced some legislation on the space grant college and fellowship program, and I anticipate reintroducing that. I frankly want to have your views on it because it could have some influence on how I structure it, and I might make some changes in it based on your views.

One part of that program would be a fellowship program for undergraduates and graduate students in fields related to space. I note that during the 1961 to 1970 period, NASA supported studies of some 5,000 scientists and engineers for doctoral degrees under what was called the sustaining university program. That created a national resource on which we continue to draw.

Now, in 1986 according to a recent report by the Business Higher Education Forum, NASA was supporting only 240 graduate degree candidates plus summer fellowships for about 300 faculty members. I have been told that the budget for the graduate research fellows is only about $1 million a year.

Do you believe that is a sufficient commitment in order to have well-trained successor generations of space engineers, scientists, so that America can continue to be a leader in space?

Dr. **Edelson**. We are very worried about that problem, Senator Bentsen. I, for one, was very glad that you brought it up in the hearing the other day with Dr. Fletcher. Immediately after we returned to NASA headquarters, Dr. Fletcher asked us to follow up on that suggestion and see what we are doing or should be doing in that regard.

Dr. Jeffrey Rosendahl was one of the people who has been working on that, and I would like to ask him to respond to your question.

Dr. **Rosendahl**. Yes, I would be very pleased to respond to your question in terms of the importance of graduate fellowships since I can speak with some personal authority, as I was one of those 5,000 NASA predoctoral fellows in the middle and late 1960s who received their graduate support——

Senator **Bentsen**. Well, you are obviously going to give us a very objective viewpoint.

Dr. **Rosendahl**. We do think that the graduate education—I might also note, by the way, that in terms of this fellowship with the national resource, I am currently carrying out a study to see what happened to those 5,000 people to see if they wound up replicating themselves as scientists or spread out to become a broader national resource for science and technology. It has proven to be a rather interesting job to actually track down as many as 5,000 people, and it will take some time but I think the results are going to turn out to be very interesting.

Clearly, the education process is central to our future. I think the support of graduate students is extraordinarily important, and we certainly appreciate the aims of the space grant program that you have proposed in terms of help to graduate education and education in general.

I think that there are many ways that we support graduate students. The 240 fellowships that we have, 120 in fact being administered by myself out of NASA headquarters, and we are just in the process of evaluating several hundred applications at the moment for those, represents really only a part of what we are doing.

By the way, the average value of those fellowships is about $18,000 a year plus an additional allowance for fees and so forth. So we are probably putting between $3 and $4 million a year into that graduate fellowship program, but that is only one of the ways in which we support graduate students.

Many of the grants that we put out at the individual universities support people in their research as part of the grants to principal investigators. The remaining graduate students who wind up being supported in research grants throughout the universities, graduate students who are associated with the suborbital programs and are doing theses with rockets and balloons and based on airplanes. We have had graduate students who are doing theses on results from the Voyager supported by Voyager funds. We have had actually and have held graduate student symposium on the first winners, people who have been working on results even from the Soviet Vega missions in the University of Chicago.

So that, in fact, I think we are recognizing the importance of graduate education, but just to look at the fellowship program is probably only to look at a part of what we are actually doing. We would certainly welcome, recognizing this importance, anything extra that could be done to help promote graduate education.

Senator BENTSEN. Well, let me get into some more of that down along those lines. I was looking at a report the other day in engineering that now foreign students in graduate work in engineering comprise over 50 percent of the students. Now, if those numbers are right, that is incredible.

One of the points they make, though, is that our student loans will take them up to the graduate level generally and have a tendency to fade out and not support the graduate work, where other nations are supporting their students to do that. In this era of intense competition, the role of scientists and engineers has become critical, terribly important.

So a second aspect of that bill of mine is a space grant college program to foster concentrations of space-related research at designated educational institutions and regional consortia. That concept has been endorsed by the Business Higher Education Forum. That is headed by Rockwell's Robert Anderson and Cal Tech's Marvin Goldberger, and the report by Dr. Lanzerotti's committee also praises interdisciplinary multiinstitutional collaborative research teams for some projects.

Now, do you agree that such a program of space grant institutions could enhance and supplement NASA's current university research activities?

Dr. ROSENDAHL. I guess my feeling in having examined the proposed legislation in considerable detail is that we support the general aims that we are certainly working on fostering graduate education, on interdisciplinary research, on new modes to participation consortia, and have the universities as major participants, and have had for quite some time.

I think we do have some concern about the nature of the administrative machinery which is associated with the proposed legislation as perhaps being unduly cumbersome and perhaps somewhat restrictive and that could perhaps, if not some care is taken, actually decrease the university participation in our program rather than having what I believe is the laudible intended aim of the legislation and increase it.

Senator BENTSEN. Well, we better get together and work on the mechanics and see if we can achieve what we both agree is a worthwhile objective.

I refer you to the President's State of the Union Address when he called for a competitiveness initiative, and in that he specifically said included in the initiative new university-based interdisciplinary science and technology centers as well as multiyear joint research programs with consortia of U.S. firms and universities.

Now, the space grant college program seems to fit that mode. It has the same basic shape as the new presidential proposal. Now, what is NASA planning as a part of this competitiveness initiative? Is the space grant college program consistent with those kinds of plans? Have you really gone and looked at what the President is talking about now, that is in the last month?

Dr. **Rosendahl**. I might say that we are already fostering interdisciplinary research in the earth sciences. For example, we have a major program under way in areas like solar terrestrial theory where we are supporting large groups at a number of universities. We have work under way in astrophysical theory. We have established centers of excellence in microgravity science, so we in fact believe that we have under way a very significant number of activities and have had for some time which are entirely consistent with the aims which were stated of fostering competitiveness and fostering these new kinds of activities as stated in the President's message.

We think we agree with it because we think we have already been doing it for some time.

Senator **Bentsen**. Well, let us see if we cannot buttress it and do it even better. That is why I would urge very strongly that the people who are responsible for that area of development work with my staff and my staff with yours to see if we can structure this to accomplish these common objectives.

Dr. **Rosendahl**. I think we would be very pleased to take the time and sit down with you and your staff and to work with you to make sure that we achieve these important objectives and do it in a way that is best for the country.

Senator **Bentsen**. Thank you very much, Senator.

Senator **Rockefeller**. Thank you, Senator Bentsen. Just one final question from me before we go onto the next panel. This might have been touched upon earlier by Senator Riegle.

The Advanced Communications Technology Satellite, seems to me to be very high stakes in terms of our future, and it is basically the satellite communication technology for the next two decades. That was zeroed last year and was put back in thanks to some very good work by Senator Lautenberg. As I understand it, it is not of high priority interest to you all this year, the theory being, I suppose, that these things can be handled by the private sector and that, in fact, they will be handled by the private sector.

It is an area where we have, and it is one of the relatively few areas where we have maintained some global leadership. We still do, but we clearly are not going to maintain it if we do not go after it.

Now, there is another theory which says that it is too risky for private industry and that private industry, in fact, will not get into it. I would like to get, Dr. Edelson, your view of the priority of an advanced communication satellite, why you have either evidence to feel that the private sector will get into it or if, in fact they will not, or is it of lesser concern to you than other priorities within a tough budget?

Dr. EDELSON. My opinion, Senator Rockefeller, is that it is a very valuable program and a very high priority to the nation to develop the technology in the ACTS program. It should be clear that NASA did propose to continue the program. We, in fact, have increased the funding in the Fiscal Year 1987 program in order to expedite the work and get the most effective work done.

NASA did propose a continuation of that work in its budget submission, and it is my understanding that the administration through the OMB took the same action on ACTS that they did on all other recissions of a similar nature, and that there was no specific determination this time.

We heard during the budget submission that OMB did contemplate zeroing the budget in fiscal year 1988, and NASA submitted what we call a reclaim for that, but we were caught in the administrative decision to follow the statement that was made last year.

Senator ROCKEFELLER. Well, if the Congress funded it, would there be a slot for it on a manifest?

Dr. EDELSON. Absolutely, yes sir.

Senator ROCKEFELLER. By any predictable date?

Dr. EDELSON. We have conducted some studies that would allow us to launch it with other payloads. It does not require a complete Shuttle devoted to that payload, and we have conducted studies which are very promising which indicate that it could be launched with other payloads as early as 1990.

OPENING STATEMENT BY SENATOR ROCKEFELLER

Senator ROCKEFELLER. All right, I have a statement that I will insert in the record of my own, and Chairman Hollings has one that will be submitted for the record.

I would first like to welcome Dr. Edelson and the three distinguished panel members here today to discuss what, in my mind, is one of the most essential functions of NASA: space science and applications.

Last year, as most people in this room know, was to be NASA's "Year of Space Science"—but tragically that was not to be. The Challenger disaster set back the entire space program, but most especially the space science programs. We now face the challenge of rebuilding American leadership in space science and technology. And it is an area of leadership in which we can ill afford to fall behind.

But recent reports by the National Academy of Science and NASA's own Space and Earth Science Advisory Board suggest that America has lost its former pre-eminence in space sciences to the West Europeans and the Japanese. Now is a time to redouble our efforts in space science research—yet the FY88 NASA budget request appears to compound the problem by underfunding space science projects. Space science and applications represents a smaller and smaller share of NASA's overall budget, dropping from 19% of the budget in 1986 to just under 16% this year.

I appreciate that enormous problems have been posed by the shuttle disaster, and that many experiments involving microgravity materials processing, for example, have been delayed by the manifest backlog. I do hope, however, that there will be serious consideration given by NASA to procuring expendable launch vehicles to take some of the pressure off the Orbiter manifest—especially for the space science missions which have gotten rather low priority.

Our Nation's future depends critically upon our ability to innovate and to compete in the international marketplace. Some of our best brains are at NASA and working in our universities on NASA projects—and the Agency has produced a stunning record in terms of commercial applications of NASA research. I am convinced that NASA has and will continue to have a critical role to play in keeping America on the cutting edge of science and research, and I look forward to working with you towards that goal.

[The statements follow:]

OPENING STATEMENT BY THE CHAIRMAN

Today, this Subcommittee will review the FY 1988 NASA budget request for the Office of Space Science and Applications. More than any other area within NASA, the effects of the Challenger disaster are most evident in the space science arena. In 1986, the United States was to launch three major space science missions—Galileo, Ulysses, and the Hubble Space Telescope. Voyager was to encounter Uranus, and the space shuttle Astro mission was to give us a firsthand view of Halley's Comet. It was to be the Year of Space Science. But, of course, the Challenger tragedy changed all of that.

Currently, the Space Telescope is scheduled for launch in November of 1988, Galileo in September 1989 or October 1990, and Ulysses in September 1989 or October 1990, depending on the Galileo flight date. However, there is still much discussion about this proposed space shuttle and whether other missions could be substituted, such as the Mars Observer Mission for the Ulysses Mission, and whether it would be prudent to use expendable launch vehicles as well as the shuttle. In addition, there is much discussion about the overall status of space science missions on the shuttle manifest and the need for expendable launch vehicles to alleviate the backlog. Prior to the Challenger disaster, 50 NASA space science missions were on the shuttle manifest. Today, there are only 17!

For years, members of the science community argued that NASA's space science and applications missions were adversely impacted by the shuttle program. Today we are hearing similar arguments, except now the space station program is the villain. Today, we will explore both of these concerns and one of my own—why the United States can't seem to afford to provide NASA with enough resources to support both the manned space program and the space science program.

We are fortunate to have at today's hearing four witnesses who clearly understand the current status of the NASA space science program, its value to the U.S., and the challenges of the future. I am optimistic that today's discussions with Doctors Edelson, Sagan, Nagy and Lanzerotti will do much to improve the Subcommittee's understanding of the current situation and its affect on the health and wellbeing of the Nation's space science and applications program. I also am optimistic that today's discussion will highlight to NASA and the Administration that this Subcommittee and the Congress continue to support a balanced space program—manned and unmanned—and that the NASA mixed fleet decisions have been forestalled too long.

Senator ROCKEFELLER. There are a number of committee members who are not here who do have questions, and they will be submitted for your answers to the record.

Having said that, I am grateful to you, gentlemen and ladies, for your presence and your cooperation.

[The statement follows:]

STATEMENT OF DR. BURTON I. EDELSON, ASSOCIATE ADMINISTRATOR, SPACE SCIENCE AND APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman, members of the Subcommittee: I am pleased to be here to present the proposed FY 1988 budget for the NASA Space Science and Applications program. Over the past 28 years, this program has consistently made significant contributions to our scientific knowledge of the universe and our own planet Earth and developed practical areas of space systems and technology for the benefit of all mankind.

The year 1986 began as one of anticipation for the Office of Space Science and Applications (OSSA). It was heralded as "The Year of Space Science" in recognition of the large number of major space science flight activities which we expected to come to fruition in that single year. In January, the *Voyager 2* spacecraft, launched in 1977, would make a remarkable encounter with the planet Uranus and would return spectacular images and other scientific measurements of the planet taken at close range. Two major planetary missions were scheduled for launch in May on the Space Shuttle: one to Jupiter (the *Galileo* spacecraft and probe) and the other over the poles of the sun (the joint NASA/ESA *Ulysses* mission). Two major Spacelab missions (ASTRO-1 in March to observe Comet Halley and Atlas-1 in August) were planned to carry out extended scientific investigations in orbit. The *Hubble Space Telescope*, scheduled for launch in August, was to begin a decade or more of exploration of the universe.

Only the *Voyager* encounter with Uranus became a reality in 1986. The loss of the *Challenger* required a massive replanning of the entire space science and applications program.

Following the *Challenger* disaster, the first priority was clearly to identify the causes of the Shuttle accident and to develop and implement a recovery plan that could get the Shuttle fleet back into service safely. NASA could then provide a solid planning base upon which Space Shuttle users (government and private) could make their own recovery plans, addressing their particular programmatic needs. When appropriate, we have consulted with our international partners so that they would be able to adjust their activities.

OSSA was an active participant in the Agency studies and planning exercises carried out in 1986 to reestablish a workable Shuttle manifest and to address the programmatic impacts of the schedule delays. We carried out our own assessments of launch and schedule requirements for programs and initiated analyses of expendable launch vehicles now incorporated into the "Mixed Fleet" study carried out by the Office of Space Flight.

We have been working hard to set a plan for recovery of the program, and to maintain the health of the Space Science and Applications program and have had to make some very hard choices. A critical element in our plan to maintain momentum during the Shuttle hiatus is our "Vitality Package". It will provide an infusion of research funds to support university research and continue to promote the space sciences to graduate students as a viable research option during the hiatus of flight opportunities. The research will focus on two areas that desperately need attention: increased attention to the suborbital program as the only current source of flight opportunities and the continuation of basic research and data analysis from previous flight missions. This package provides for the reallocation of funds from the baseline program in order to maintain vitality for the university research community. It will provide immediate research opportunities, and is directed to the shorter range needs pending the resumption of normal payload development and flight opportunities. Vitality funds do not initiate major long-term obligations. I will talk about our plans and the program funding requirements in a minute. Before doing so, however, I'd like to highlight several of our major achievements during the past year.

HIGHLIGHTS

Voyager 2 Encounter with Uranus

On January 25, 1986 the *Voyager 2* spacecraft provided our first detailed look at the seventh planet Uranus, nearly 3 billion kilometers from the Sun, a world so distant that it was only discovered through a telescope 200 years ago.

Close up, Uranus turned out to be even more different that we had suspected. Its blue-green atmosphere is almost featureless, and scientists could detect structural details only after careful processing of the imaging data. Over the poles, the atmosphere contains a high haze of methane and shows no structure at all. Single clouds appear only in the clear atmosphere within 45 degrees of the planet's equator. The planet's magnetic field, which is strong, was the biggest surprise. Like the Earth, Uranus has a dipolar field. Unlike the Earth, the axis of the field is oriented at the remarkably large angle of 60 degrees from the axis of rotation, and the center of the field is offset more than 7,700 kilometers from the center of the planet. As a result, the magnetic field of the rotating planet twists and describes a corkscrew shape on the side of the planet down wind of the Sun.

Voyager 2 photographed the nine known rings that surround Uranus for the first time. The spacecraft also discovered two more rings and provided evidence that several more discontinuous ring arcs also orbit the planet. The ring material is extremely dark, similar to carbon black or soot. The moons of Uranus also provided major surprises. Ten new satellites were discovered; nine of them are much smaller than the five already known Uranian moons. The five larger moons are all dark; their surfaces show much more extensive and varied geological activity than expected. At one end of the spectrum, the moon Umbriel has a uniform dark surface possibly produced by recent blanketing of the moon by dark material. By contrast, Miranda, the smallest of the five, has a complex and totally unique surface—a patchwork of different terrains, including huge icy canyons more than 10 kilometers deep. The *Voyager 2* spacecraft continues onward toward an encounter with the planet Neptune in 1989.

The Return of Halley's Comet

1986 marked the return of Halley's Comet in its 76-year cycle around the Sun. For the first time in its 30 recorded appearances, this famous comet was tracked, observed and measured electronically, not only in the optical band but in various parts of the electromagnetic spectrum, by very sophisticated instruments from the ground, in earth orbit and in deep space.

An international flotilla consisting of spacecraft from the European Space Agency (ESA), the U.S.S.R., and Japan flew close by the comet. U.S. spacecraft, including one in orbit around Venus, also made significant observations of Halley's comet, and the NASA deep space network provided precision tracking for the international flotilla. One thousand scientists from 50 nations participated in the International Halley Watch.

Nearly three dozen U.S. scientists were involved in ESA's *Giotto* mission, which intercepted Halley's Comet on March 14, 1986, approaching within 600 kilometers of the comet's small nucleus. This very close approach was made possible only by the close cooperation established between NASA, ESA, and the U.S.S.R., under the auspices of the Inter-Agency Consultative Group in tracking and coordinating the various spacecraft missions.

Close-up observations of Halley's Comet from *Giotto* and other spacecraft discovered that the solid nucleus of the comet is a highly irregular object and much larger than expected. The surface of the nucleus is covered by a layer of black dust the thickness of which is unknown, and the surface temperature, about 330° F, is much higher than predicted. Numerous jets of dust and gas are continuously shot out of fractures in the nucleus, and that activity is limited to the sunlit side of the nucleus.

During March of 1986 the International Cometary Explorer (ICE) was targeted to a point upstream of Halley's Comet by 30 million kilometers at the same time as Halley was being investigated by the five satellites from Europe, Japan, and the U.S.S.R. From this great distance ICE detected energetic ions and plasma waves from Halley's Comet that were consistent with predictions based on the spacecraft's earlier encounter with Comet Giacobini-Zinner in September 1985. In addition, water has been detected in comet Halley. The detection was made by instruments aboard NASA's Kuiper Airborne Observatory (KAO), a C–141 aircraft operated by NASA's Ames Research Center and equipped with a 91-centimeter telescope. KAO observed the comet as it was approaching the Sun in December 1985 and again in March 1986 as the comet began receding from the Sun. This detection is very significant, because water ice is thought to be the most important single component of a comet.

Among the ground-based studies of Halley's Comet, the International Halley Watch (IHW) has been an extemely successful international program of cooperative ground-based astronomical observations. NASA and numerous U.S. scientific institutions have been actively involved in the program, and the Jet Propulsion Laboratory (JPL) in Pasadena, CA serves as one of the two administrative centers. More than 1,000 photographs of the comet have been obtained since 1984, and many IHW results were used to support the operations of the comet intercept missions. Of the more than 1,000 scientists, representing over 50 countries, participating in the IHW, more than one-third are Americans.

Infrared Astronomy Satellite

We continue to see the promise of discovery fulfilled as scientists investigate the nature of the over 250,000 infrared sources detected by the Infrared Astronomy Satellite (IRAS), a NASA-Dutch-British project launched in 1984. In 1986, a team at the University of Arizona discovered that one of the IRAS infrared sources is a young protostar—a large mass of gas and dust collapsing rapidly under the force of its own gravitation to become a star. The observations were made with ground-based telescopes directed toward promising candidates found in the IRAS catalog. Because this is the first time we have been able to see a star being born, the discovery is very significant. There are many theories on the subject, but this is the first time astronomers have a specific object on which to test them. We expect this object to be a rich source of information about how stars and planets form, especially once astronomers can resume infrared observations from space.

Satellite-Aided Search and Rescue System

COSPAS/SARSAT, the international satellite aided search and rescue program, began as an outgrowth of NASA activities. It evolved into a cooperative program among the U.S., the Soviet Union, Canada, and France and has been recently expanded to include participation by Norway, the United Kingdom, Bulgaria, Finland and Denmark. In 1986, Chile and Brazil also proposed to join the program. The system which recently completed its first year of regular operation, has already been credited with saving more than 675 lives throughout the world. This success has stimulated the participating governments to draft a new agreement to reflect their commitment to the program. Also significant was the endorsement of 406 MHz proposed by NASA as the primary frequency for the proposed Emergency Position Indicating Radio Beacon for the Future Global Maritime Distress and Safety System. Work is continuing to develop world-wide standards for the Emergency Locator Transmitters operating in the same frequency band.

Monitoring the Ozone Hole

Ozone acts as a protective shield to absorb damaging radiation from the Sun. The apparent deterioration of the ozone layer in Earth's upper atmosphere is a major concern to scientists, particularly in light of observations over the past several decades that indicate that the composition of the Earth's atmosphere is changing. These observations show that the amount of ozone in the atmosphere has been fluctuating, particularly over Antarctica. To investigate this phenomena, a group of scientists, cosponsored by NASA, the National Oceanographic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), and the Chemical Manufacturers Association (CMA) conducted an expedition to Antarctica last year. Using balloon-borne instrumentation and remote sensing techniques, they studied the ozone deterioration which had been observed. The results of this expedition will help to identify the cause of ozone breakdown, and to determine whether the change over Antartica is a precursor of changes elsewhere on the globe. In 1986, NASA completed a comprehensive report on the current state of understanding of the distribution of atmospheric ozone and susceptibility to change through natural and man-made causes. The assessment, cosponsored by NOAA, the World Meteorological Organization, the United Nations Environment Program, the Commission of the European Communities, and the Federal Republic of Germany will provide the basic data needed to advance important investigations in this critical area.

NOAA-G Weather Satellite Launch

The September, 1986 launch of the NOAA-G weather satellite on an Atlas expendable launch vehicle was picture perfect, with smooth operations and no delays through liftoff. After all systems were fully checked out and determined to be functioning properly, the spacecraft was turned over to NOAA for routine operations early in December. Now designated NOAA-10, it is providing daily global coverage in the early morning orbit.

BUDGET SUMMARY

The budget request I present today represents the level needed to carry us through the hiatus of Shuttle availability, maintain program momentum, and continue our major programs in a state of readiness for the resumption of flight.

The total FY 1988 Research and Development request for the Office of Space Science and Applications (OSSA) is $1508.3 million. This funding level will support a balanced program in the various disciplines of space science and applications and will also provide funding for the "Vitality Package" needed to sustain a healthy research base through the Shuttle flight hiatus.

This request provides funding for a proposed new start, the Global Geospace Science (GGS) program, which will build on the collaborative Solar-Terrestrial Research Program initiated in 1987 as a cooperative effort with the European Space Agency (ESA) and the Japanese Institute of Space and Astronautical Science (ISAS). Two new U.S. missions, Wind and Polar, will be combined with the Japanese Geotail mission and the Combined Release and Radiation Effects Satellite (CRRES) to make coordinated measurements and obtain the first comprehensive, multi-point study of global magnetospheric response to solar wind. These missions, along with ESA's contribution, SOHO and Cluster, make up the International Solar-Terrestrial Physics (ISTP) program. GGS will provide a major advance in our understanding of solar-terrestrial physics and will assure a key role for the U.S. in this important field.

This budget will maintain the critical momentum needed to carry the Space Science and Applications program through the hiatus of flight opportunities, and to be prepared to move forward when Shuttle flights resume. It will support the testing and certification of the Hubble Space Telescope, the centerpiece of the space science program. It will support the *Galileo* mission to Jupiter and the Ulysses mission which will provide our first view of the Sun and solar system from above the ecliptic plane. It will support the Ocean Topography Experiment (TOPEX) which will give global coverage of ocean surface currents and measure them with high precision and accuracy over long periods of time. It will continue development on other exciting and important programs, including the Gamma Ray Observatory, the *Magellan* mission to Venus, the Upper Atmosphere Research Satellite and the Mars Observer. It will support critical activities in Life Sciences and additional effort in the Microgravity Science and Applications disciplines as well as planning for the utilization of the Space Station.

The budget will also support the continuation of the Explorer program, and the activities necessary to maintain readiness of Spacelab and other Space Shuttle Payload missions when flights resume. It will also support our development work on instruments and facilities for early use of the Space Station, and provide the funds needed to implement the Vitality Package to make maximum use of our broad-based research and analysis capability.

Consistent with Administration policy that the development of commercially oriented technology should be left to the private sector, we are not requesting FY 1988 funds for the Advanced Communications Technology Satellite.

The FY 1988 budget request for Science and Applications will maintain a strong program through the Shuttle flight hiatus, and ensure our readiness to implement our approved missions as soon as practically possible. The details of the FY 1988 budget request are displayed on Charts 1 and 2. I will now briefly review some of the major elements of the program.

PHYSICS AND ASTRONOMY

In FY 1988, we request $567.1 million for our Physics and Astronomy program, which includes Spacelab, Astrophysics, Explorer, and Suborbital activities.

In the Astrophysics program, NASA is poised to bring the world a whole new look at the universe around us. Discoveries continue to be made using the results of IRAS and the high Energy Astronomy Observatories (HEAO) and from new observations with the International Ultraviolet Explorer (IUE) and the Solar Maximum Mission (SMM). But a new age of understanding will begin when we launch the first two of the Great Observatories in space—the Hubble Space Telescope (HST) and the Gamma Ray Observatory (GRO). By the time we complete the Great Observatory program with the Advanced X-ray Astrophysics Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF), astronomers will have for the first time the ability to simultaneously observe the universe with high sensitivity over the entire electromagnetic spectrum. They will be able to investigate the secrets of the universe unhindered by the distorting and absorbing atmosphere that blocks all frequencies except the information carried by visible light and radio waves. We eagerly anticipate this coming era of great scientific achievement.

The Great Observatories are complemented by smaller Explorer and Spacelab missions that investigate special problems in astrophysics such as performing the first surveys of the sky at wavelengths accessible only from space. Finally, the entire flight program stands on a scientific and technical base developed by our supporting programs of Suborbital flight and Research and Analysis.

Hubble Space Telescope

The Hubble Space Telescope (HST), originally for launch in the fall of 1986, is now expected to be launched in the summer or fall of 1988. We still regard it as potentially the most significant tool for scientific discovery in our lifetime.

For FY 1988, we request $98.4 million for development activities to prepare for launch readiness and $93.7 million for preparations for on-orbit operations and maintenance of the HST. Our forecast that the HST will provide a major leap in sensibility, resolution and precision in astronomical observations has now been supported by extensive ground testing of the entire observatory system. By the summer of 1986 HST had completed an extensive, rigorous and realistic series of tests, including a thermal-vacuum test, which simulated the actual environment of space. Concurrently, the ground system control, communications and science data return were exhaustively tested. The test results provided convincing evidence that the HST observatory will meet or exceed the original performance objectives. The pace of post-test and pre-ship activities has been reduced in keeping with the adjusted launch schedule. A period of active storage during spring and summer of 1987 will be followed by the confidence tests, pre-ship tests, shipment to Kennedy Space Center (KSC), and launch. The ground elements of HST are launch ready, but will undergo further enhancements previously scheduled for the post-launch period. In addition, further operating tests are being conducted to calibrate and standardize their functions. Plans for servicing are well advanced, and procurement of hardware items are in progress to support servicing on orbit after launch of the HST spacecraft.

Gamma Ray Observatory

For FY 1988, we request $49.1 million to begin integration and testing of the complete observatory. When it is launched in 1990, the Gamma Ray Observatory (GRO) will present to astronomers a dramatic improvement in sensitivity and resolution for observations of gamma rays emitted by such violently active objects as quasars, pulsars, and black holes. The least energetic phenomena to be observed by GRO are remote nuclear processes and regions where the temperature reaches a billion degrees; at the most energetic, the gamma rays observed by GRO will tell us about subatomic collisions in space that are 100,000 times more energetic still. Development and testing of instruments continues and assembly of the spacecraft structure will be completed in FY 1987.

Explorer Program

We request $60.3 million to continue the definition and development of the relatively small and complementary missions of our Explorer series, which have yielded so many important scientific results.

The Cosmic Background Explorer (COBE) is now being planned for launch in 1989 to seek new knowledge about the earliest observable stages in the evolution of the universe. COBE's cryogenically cooled instruments will search in the spectral region from the near-infrared to microwave frequencies making an all-sky map of the diffuse cosmic background radiation and measuring the spectrum with great precision. During 1986 COBE's two cryogenically cooled instruments, the Diffuse Infrared Background Experiment (DIRBE) and Far Infrared Spectrometer (FIRAS), were successfully tested in a dewar at a few degrees above absolute zero. The mission requires a nearly polar orbit, and we have begun modifying COBE for launch on a Delta vehicle from the Western Test Range.

The Extreme Ultraviolet Explorer (EUVE) will conduct the first high-sensitivity survey in a wavelength band between ultraviolet light and X-rays, and it will perform spectroscopic investigations of selected sources as well. The EUVE payload is under development at the University of California at Berkeley in preparation for a Critical Design Review in 1987. Final testing is planned for 1988. The X-Ray Timing Explorer (XTE) will extract information about neutron stars and black holes from fluctuations in the intensity of the X-rays they produce. In 1987, work will continue on XTE instrument technology and systems definitions.

The Roentgen Satellite (ROSAT) is a cooperative program involving the United States, the Federal Republic of Germany (FRG), and the United Kingdom (UK) to make a full-sky survey in the X-ray portion of the spectrum. The FRG is building the spacecraft, a focusing X-ray telescope and two of the three planned focal plane instruments. The United States is supplying the launch and the third focal plane instrument, a High Resolution Imager (HRI). The HRI is due to be shipped to Germany early in 1987 for integration and testing. Other 1987 activities will concentrate on preparing the U.S. ROSAT Science Data Center at the Goddard Space Flight Center for operation.

In 1986, NASA selected United States investigators to work as part of a U.S./Japanese team to develop a soft X-ray telescope for the Japanese SOLAR-A mission. The Japanese plan to develop the other major instrument and launch their mission to study solar activity in 1992.

Mission Operations and Data Analysis

The FY 1988 request of $128.1 million will support preparations for launch, operation and future maintenance of the Hubble Space Telescope (HST), continued operations and data analysis support for the Solar Maximum Mission (SMM) and International Ultraviolet Explorer (IUE), and the analysis of data from the Infrared Astronomical Satellite (IRAS) and the High Energy Astronomy Observatories (HEAO).

The Solar Maximum Mission (SMM) is returning excellent data on the Sun during the transition from one solar cycle to the next. Solar activity reaches a peak of intensity every eleven years, and SMM has been observing this activity since the last peak in 1980. Activity on the Sun is now at its lowest level, but it will soon begin building up toward another peak in 1991. After being repaired during a Space Shuttle mission in 1984, SMM continues to return data despite a failure of a Tracking and Data Relay Satellite System (TDRSS) antenna in February 1986, when it locked up during a maneuver to view comet Halley. Solar data continue to be sent directly to Earth via the S-band antenna.

The International Ultraviolet Explorer (IUE) is a joint project with the United Kingdom and European Space Agency (ESA). Although designed for only a three-year operational life, IUE is now completing its eighth year of continuous operation. The spacecraft's 18-inch telescope played a major supporting role during the international observations of comet Halley by providing the long-range reconnaissance to enable spacecraft from ESA, Japan, and the Soviet Union to make direct measurements of the comet as it passed away from the Sun. More than a thousand American astronomers have used IUE, and requests for observing time continue to rise. More than 200 new proposals were received last year from scientists in half of the United States and several foreign countries. Interest remains high, as we have received another 319 proposals for FY 1988.

The Infrared Astronomy Satellite (IRAS), a joint program with the Netherlands and the United Kingdom which made the first infrared, all-sky survey in 1983, continues to be a source of important discoveries as the data are analyzed. In a vigorous program of research, IRAS data are being provided to sceintists from around the world by the Infrared Processing and Analysis Center at the Jet Propulsion Laboratory.

During 1986, data from the High Energy Astronomy Observatories (HEAO-1, 2 and 3) continued to provide significant contributions to our understanding of the universe as revealed through high energy astrophysical processes. Continued analysis of the HEAO-2 data on clusters of galaxies, for example, has revealed the presence of X-ray emissions indicative of a large inflow of matter (approximately one thousand solar masses per year) into one such cluster. This observation of the formation of a galaxy in progress was largely unanticipated in most theories, which predicted that galaxy formation had occurred only during the very earliest epoch of the formation of the Universe.

This year, we have begun a new, coordinated, archival research program to encourage maximum use of the valuable data sets collected by our astronomical missions. In addition to analyzing data from the archives of HEAO, IRAS, SMM, and IUE, scientists can also propose to make investigations using data from the European EXOSAT mission. Early indications from the scientific community shows that interest in the Space Astrophysics Data Analysis Program is very high. This effort will be continued in FY 1988. Such a coordinated data analysis program is one example of use of the "Vitality Package" allocation.

PLANETARY EXPLORATION

The FY 1988 budget request for Planetary Exploration is $307.3 million. This amount includes funds for continued development of several missions: the *Galileo* orbiter/probe to Jupiter, the *Ulysses* mission to explore the poles of the Sun, *Magellan* (formerly the Venus Radar Mapper), and the Mars Observer. It also includes funds for the operation of existing spacecraft, supporting activities, and ground-based research.

Galileo

In FY 1988, we are requesting $55.3 million for continued development of the *Galileo* mission, a joint project between NASA and the Federal Republic of Germany

(FRG). This mission is planned to make a comprehensive, long-term study of the giant planet Jupiter, its atmosphere, huge magnetic field, and large and unusual moons. The spacecraft has two parts: an Orbiter to make the long-term surveys and a Probe that will enter Jupiter's atmosphere and make direct analyses of its composition.

Galileo was ready for launch in May 1986 on a *Shuttle/Centaur* combination. The *Challenger* accident in January, 1986 forced a postponement of the launch. The subsequent cancellation of the *Shuttle/Centaur* upper stage because of Shuttle safety concerns forced a further re-evaluation of the mission because no other available upper stage is powerful enough to insert *Galileo* into a direct Earth-Jupiter trajectory.

Present plans call for *Galileo* to be launched with a Shuttle/Inertial Upper Stage (IUS) combination on an initial trajectory toward a Venus swingby, followed by two Earth swingbys, using the three gravitational assists to obtain the energy required for a trajectory to Jupiter.

During 1986 a significant effort was made to study various launch and trajectory possibilities, leading to the one currently planned. Studies were also conducted to determine the changes that need to be made to the spacecraft in order for it to fly the new trajectories. These changes are chiefly in thermal control design because the spacecraft, in passing Venus, will be going closer to the Sun than originally planned. During 1987 these thermal control changes will be implemented; in addition, certain changes will be made to improve the reliability of the spacecraft computers. These changes will be tested during 1988 to assure that the spacecraft will perform properly on its new mission profile.

Ulysses (Solar Polar Mission)

In FY 1988, we are requesting $10.8 million for continued development of the *Ulysses* mission, a cooperative effort between NASA and the European Space Agency (ESA). *Ulysses* will provide our first view of the Sun and the solar system from above the ecliptic plane.

By observing the Sun and its surroundings from a wide range of solar latitudes, *Ulysses* will make detailed observations of the structure of the Sun's magnetic field and the nature of the streams of atomic particles ejected from the Sun in solar wind and solar flare eruptions. These data will provide previously unavailable fundamental data about the Sun and will help us to better understand the effects of the Sun's activity on the Earth's weather and climate.

The *Ulysses* launch on board a *Shuttle/Centaur* was originally scheduled for May, 1986. It has been postponed due to the *Challenger* disaster and the subsequent cancellation of the *Centaur* upper stage. Current plans now call for launching *Ulysses* in either September 1989 or October 1990, using the Shuttle and IUS/PAM-S launch stages. The final decision on the launch date will be coordinated with our European partners.

During 1986, spacecraft pre-launch testing at the Kennedy Space Center (KSC) was completed and the spacecraft was returned to ESA for storage. The science instruments were returned to the investigators for storage and periodic checkout. Mission design efforts were initiated to support the new mission profile and launch dates. During 1987, as the launch date becomes more definite, this effort will concentrate on details of the new launch, the interplanetary trajectory, and mission operations planning. Activities will also continue to make the spacecraft compatible with the new launch vehicles. In 1988, activities will focus on completion of the new spacecraft/launch vehicle documentation, launch approval activities involving the Radioisotope Thermoelectric Generator (RTG), and the plans for retesting the spacecraft and the science instruments.

Magellan (Venus Radar Mapper)

FY 1988 funds of $59.6 million are requested to continue development of the *Magellan* mission. This spacecraft will map the surface of the planet Venus from orbit, using a radar instrument to pentrate the thick, permanent clouds that hide the planet's surface. The radar images will provide essential data on the planet's geology, topography, structure, and evolution, so that we can begin to understand Venus as well as we now do Mars, Moon, and Earth.

Magellan is currently planned for launch in April, 1989, on a Shuttle/Inertial Upper Stage (IUS) vehicle. After reaching Venus in July 1989, *Magellan* will map the major portion of the entire planet during a period of eight months, with a ground resolution of about 150 meters.

During 1986, the mission was readjusted to accommodate a one-year delay caused by the *Challenger* accident and cancellation of the originally planned Cantaur upper stage. Progress was made in completing and testing the development model of the radar. Considerable progress was also made in the build-up of the structure and subsystems for the flight spacecraft.

In 1987 the flight model of the radar instrument will be built, tested, and delivered. The flight spacecraft will be assembled, and the radar system and the subsystems will be integrated and undergo initial environmental tests. Final design reviews will be held for mission design and mission operations for the 1989 launch opportunity. In 1988, all efforts on the flight spacecraft will be completed, and it will be shipped to KSC for launch preparations.

Mars Observer

In FY 1988, $29.3 million is requested to support continued development of the Mars Observer mission, which was approved as a new start in FY 1985 as the first in a series of Planetary Observer missions to explore the inner solar system. The mission, planned for launch in 1922, will place a remote-sensing spacecraft in a near-point orbit around Mars, from which it will determine the planet's surface composition, atmospheric composition and dynamics, topography, magnetic and gravitational fields, and other global characteristics over a full Martian year (about two Earth-years).

During 1986, RCA was selected as the contractor for the Mars Observer spacecraft; and the Preliminary Design Review was completed. The prime contractor for the upper stage launch vehicle was also selected. Orbital Sciences Corp. Their major contractor is Martin Marietta. Development activities for the upper stage are well underway at both institutions. Another important milestone last year was the selectin of an excellent group of science investigations, including an imaging system; accommodation reviews have been completed with all the experimenters.

During 1987 final confirmation of the science investigation payload will be completed, and the spacecraft Critical Design Review will be held. A Preliminary Design Review for the Mission Operations System has been conducted. In 1987 and 1988, the scientific content of the mission will be expanded by the selection of a group of Participating Scientists to complement the instrument-oriented investigations already selected.

Mission Operations and Data Analysis

The FY 1988 request of $77.0 million will support five major operating spacecraft: *Voyager 1* and *2*, Pioneer *10* and *11*, and the Pioneer Venus Orbiter. Minor support is also provided for four other operating spacecraft: *Pioneer 6, 7, 8,* and *9*.

Voyager Program.—Voyager 1 and *2* continue to explore the outer solar system, outward bound on trajectories that will take them into interstellar space. *Voyager 1,* launched on September 5, 1977 is well past the orbit of Uranus and continuing to climb out of the plane of the solar system. From this unique path, it continues to send information about the nature of interplanetary space in that distant part of the solar system.

In January, 1986 *Voyager 2* (launched on August 20, 1977) became the first spacecraft to fly past Uranus. In this encounter, the spacecraft transmitted more than 7,000 images of the planet, its rings, and moons, together with a large amount of other planetary data. *Voyager 2* is now headed for its final planetary destination, the eighth planet Neptune, more than 4.5 billion kilometers from the Sun. Arriving at Neptune in August 1989, *Voyager 2* will provide the first close-up study of Neptune and its giant moon Triton.

Pioneer Program.—Pioneer 10 (launched in 1972) and *Pioneer 11* (launched in 1973), both continue on their way outward bound into interstellar space, exploring the interplanetary medium in the outermost parts of the solar system. Their primary goal is to define the heliopause, the boundary between the Sun's magnetic field and true interstellar space. *Pioneer 10* is about 38 astronomical units from the Sun. *Pioneer 11,* traveling in the opposite direction, is now between the orbits of Uranus and Neptune. *Pioneer 11* played an invaluable role in *Voyager's 2* encounter with Uranus by monitoring the solar wind during the encounter.

Pioneer Venus Orbiter (PVO), launched in 1978, continues to return data from orbit around Venus. In early 1986, the spacecraft successfully carried unique observations of Comet Halley when the comet was "behind" the sun as seen from Earth. the spacecraft's Ultraviolet Spectrometer made daily observations of the comet's behavior during its most active period, obtaining data on the comet's chemical composition and its rate of water loss. The same instrument also mapped a huge cloud of hydrogen gas, more than 20 million kilometers in kilometers in diameter (15 times as large as the Sun!) which forms the outer layer of the comet's coma. Observed changes in the shape and brightness of this hydrogen and cloud provides evidence of varying pressure of solar radiation against it.

As the orbit of PVO around Venus slowly changed, other instruments made important new measurements of the comet-like interaction of the solar wind with Venus itself, providing a range of coverage at new planetary latitudes. The data gathered in 1986 are especially important because of the minimum solar activity going on at that time.

The orbit of PVO is gradually decaying as a result of atmospheric drag, and in 1992 the spacecraft will finally enter Venus' atmosphere and burn up.

Flight Mission Support.—In 1986 the Mission Control and Computing Center (MCCC) under the direction of the Jet Propulsion Laboratory's Flight Project Support Office, successfully supported the *Voyager 2* encounter of Uranus. The unique data from this encounter was obtained almost flawlessly in both real-time and batch processing modes and was rapidly analyzed by the new Multi-mission Imaging Processing Laboratory (MIPL) to produce the striking and scientifically important images of Uranus, its rings, and surprising moons. The MCCC also successfully supported the *Giotto* encounter with Halley's comet, as well as the observations of the comet by the *Pioneer Venus Orbiter* spacecraft.

In addition to supporting encounter missions, the MCCC also completed the Ground Data Systems testing for the previously planned May 1986 launch of the *Galileo* and *Ulysses* missions. Significant advances were also made in designing the new Space Flight Operations Center (SFOC) by using a prototype facility. The SFOC is being designed to provide a multi-mission ground data system capability that will be both cost-effective and scientifically productive.

During 1987 and 1988, the design for the development of the SFOC baseline facility will be completed, and the existing prototype facility will be adapted to support the *Magellan* mission, now planned for launch to Venus in April, 1989. Work will also begin on the further modifications neded to support the continued operation of the *Voyager* missions, the delayed launches of *Galileo* and *Ulysses,* and the *Mars Observer* mission.

Research and Analysis

Ground-based telescopic studies were conducted in 1986 and 1987 to support the *Voyager 2* encounter with Uranus, the ESA and U.S.S.R. encounters with Comet Halley, and to prepare for the *Voyager 2* encounter with Neptune in 1989. The Comet Halley observations were especially important in providing targeting information for the ESA *Giotto* and the U.S.S.R. *VEGA* spacecraft.

Other support was provided through a number of diverse planetary science research programs involving planetary geosciences, planetary atmospheres, and the study of such extraterrestrial materials as lunar samples and meteorites. In particular, continuing scientific studies of Venus, using data from the U.S.S.R. spacecraft, and of Mars, using *Viking* data, are providing the critical scientific baseline for the forthcoming *Magellan* and *Mars Observer* missions to Venus and Mars respectively.

In addition, substantial progress was made in developing the Planetary Data System (PDS), a system which will assure the acquisition, care, and analysis of both past and future planetary mission data sets. Finally, the effectiveness of the recently-begun Planetary Instrument Definition and Development Program (PIDDP) was demonstrated in 1986 when nine instruments, all developed or improved during that program, were selected as parts of the payloads for the planned *Mars Observer* mission and unapproved Comet Rendezvous/Asteroid Flyby (CRAF) missions.

These research activities will continue in FY 1988, with several special goals: to upgrade the Planetary Data System by establishing five remote discipline-oriented computer modes, to prepare for the *Voyager 2* encounter with Neptune, and to support the *Magellan* and *Mars Observer* missions, now scheduled for launch in 1989 and 1992 respectively. In addition, analysis of data obtained in Uranus by *Voyager 2* and a wide range of fundamental research on solar system properties and evolution will continue, and the development of new instruments will be undertaken to meet future flight opportunities.

EARTH SCIENCE AND APPLICATIONS

In FY 1988, $470.6 million is requested to support the Earth Science and Applications programs identified under the categories of Solid Earth Observations and Environmental Observations. The request will also support an exciting and important new start, the Global Geospace Science (GGS) mission.

Global Geospace Science (GGS)

We are requesting $25.0 million in FY 1988 to develop two new spaceflight missions, *Wind* and *Polar*, as part of a comprehensive science program to measure, model and understand the solar influence on the Earth's neighborhood called Geospace. This influence is to be measured by the *Wind* and the *Polar* spacecraft in conjunction with the Japanese *Geotail* mission. From these measurements, quantitative models will trace the energetic plasma particles and fields in the solar wind through acceleration and storage in the Earth's magnetosphere to the ultimate deposition in the Earth's atmosphere. In the polar regions, this energy deposition equals the solar radiant energy input and therefore has a significant influence on the atmospheric energy balance. From the GGS results, predictions of disruptive effects on the ground and in space will be more quantitative as we will better understand the dynamics of the Geospace system. GGS is the major U.S contribution to the International Solar-Terrestrial Physics (ISTP) program planned together with the Japanese Institute of Space and Astronautical Sciences (ISAS) and the European Space Agency (ESA). It will help maintain a key U.S. role in solar-terrestrial research by involving more than 200 scientists from 17 U.S. Universities, 3 NASA Field Centers, 7 Research Laboratories and 14 Foreign Countries. The ISTP program also includes the complementary Collaborative Solar-Terrestrial Research initiative approved in the FY 1987 budget for U.S. instruments on ISAS's *Geotail* and ESA's *SOHO* and *Cluster* missions to monitor long term variability of the sun, investigate the origin of the solar wind, and reveal the nature of universal plasma processes that are found within Geospace.

Upper Atmosphere Research Satellite (UARS)

We request $95.4 million to continue development of the UARS observatory which was approved as a new start in FY 1985. The UARS program is directly responsive to NASA's mandate to develop and implement a comprehensive program of research, technology, and monitoring of atmospheric phenomena. Instrument development began for the UARS payload in 1982 to develop the complex, remote-sensing instruments that pace the UARS program. As a result of the *Challenger* accident, the launch of the UARS observatory has been rescheduled from 1989 to late 1991. UARS will be the first satellite capable of simultaneous measurement of energy input, chemical composition, temperature and winds of the upper atmosphere, including the ozone level. In 1986 all but one of the ten UARS instruments successfully completed their Critical Design Review and development of the observatory continued. In 1987 flight instrument assembly will be completed and testing will begin. Also, Preliminary Design Reviews will be held for the observatory and Central Data Handling Facility (CDHF). In 1988 Critical Design Reviews will be held for the observatory and CDHF and four instruments will be delivered. Instrument deliveries, including one British and one Canadian-French instrument, will be completed in 1989 and integration and test will begin. Software for data processing and interpretation will be delivered by the Principal Investigator teams in 1989.

Ocean Topography Experiment (TOPEX)

FY 1988 funds of $90.0 million are requested to continue development of the TOPEX mission. TOPEX will use an advanced radar altimeter and tracking system to measure the surface topography of the oceans, from which information on ocean circulation can be determined. TOPEX is planned as a joint mission by NASA and the French Space Agency (CNES). The CNES contribution includes an *Ariane* launch for NASA's TOPEX satellite and provision of French instruments. Scheduled for launch in late 1991, a three year mission is planned. In 1987 a satellite contractor and a science team will be selected, and sensor and ground data system development will begin. In 1988 we will conduct a Preliminary Requirements Review (PRR) and continue developing satellite and ground data systems. Sensor development will continue through Critical Design Review leading to actual construction by late 1988. The science team will also refine research plans and design options.

NASA Scatterometer (NSCAT)

The FY 1988 budget request includes $22.7 million to continue development of the *NASA Scatterometer* (NSCAT), a radar system which was planned to be flown on the U.S. *Navy Remote Ocean Sensing Survey* (N-ROSS) satellite in 1990. Since the Navy has announced the cancellation of N-ROSS, we are studying alternatives to accommodate the critical NSCAT mission in the TOPEX timeframe. The most viable of these appear to be the Air Force *Defense Meteorological Satellite Program* (DMSP), the *Space Test Program* (STP), or TOPEX. The Air Force options are being studied at the joint request of the Navy and NASA (Air Force was an N-ROSS partner) so as to continue the critical elements of N-ROSS. The FY 1988 budget request would support launch of NSCAT and DMSP in late 1990 should a decision be made to adopt that approach.

NSCAT is designed to make accurate measurements of the surface wind over the oceans. It will provide a capability to undertake the first global study of the variability of marine winds. In concert with TOPEX, it will enable an understanding of how atmospheric winds drive the circulation of the world oceans. Continued development of the Alaska Synthetic Aperture Radar Facility (ASF) is included in the NSCAT request. The ASF will be equipped to receive, process, analyze, and archive SAR data from the first *European Remote Sensing* satellite (ERS-1), under an agreement with ESA, which has a planned launch date of early 1990. By this time the ASF will be capable of producing high resolution images of Alaska, portions of northwest Canada, and the oceans surrounding Alaska from data relayed to ASF from the ERS-1. NASA also plans, subject to agreement with Japan, to receive SAR data at the ASF from Japan's Earth Resources Satellite (JERS-1) which is planned for an early 1991 launch. In 1987 various hardware components will be delivered, construction of the radio frequency subsystem started and a Critical Design Review held. FY 1988 plans include continued hardware development, testing and integration of the flight hardware, delivery of the second computer system, and continued refinement of post-launch research and verification.

Solid Earth Observations and Environmental Observations Payloads and Instrument Development

The FY 1988 budget request contains $43.6 million for continued development of Earth Science and Applications Shuttle and Satellite Payloads. These include the Tether satellite System, and reflight of some instruments previously flown on the Shuttle, for example, Measurement of Air Pollution from Space (MAPS), Atmospheric Trace Molecule Spectroscopy (ATMOS), Feature Identification and Location Experiment (FILE), and Active Cavity Radiometer (ACR-1).

To prepare for reflight of these instruments, refurbishments and modifications will be needed, followed by reflight qualifications. Instruments such as ATMOS will conduct important ground observation programs; others will be placed in storage with periodic planned calibration checks. Data processing, analysis and archiving from the previous missions continue, as well as aircraft flights for correlative measurements and shuttle mission simulations to aid in instrument interface verification for Shuttle mission planning.

We will continue to define, design, and construct advanced instruments such as the Shuttle Imaging Radar-C (SIR-C), the Shuttle Imaging Spectrometer Experiment (SISEX), and the Shuttle Light Intensity Detection and Ranging (LIDAR) instrument for global measurements of clouds and atmospheric aerosols.

Mission Operations and Data Analysis

In FY 1988, $26.8 million is requested for Earth Science and Applications Mission Operations and Data Analysis to support operations and the processing, validation, and analysis of data from currently orbiting spacecraft. *Nimbus*, Solar Mesospheric Explore (SME), and Earth Radiation Budger Experiment (ERBE) satellites continue to provide valuable information about the atmosphere and oceans. Also, operations, data analysis and scientific interpretation continue among fifty Principal Investigator teams associated with the Space Plasma Physics operating satellites: the Interplanetary Monitoring Platform (IMP-8), the International Sun-Earth Explorers (ISEE-1 & 2), the International Cometary Explorer (ICE), the Dynamics Explorer (DE-1), and the Charge Composition Explorer (CCE). In September, 1986, the third, and final set of the ERBE measurement system was launched into orbit aboard NOAA-10, and is now operating as designed. During FY 1988, ERBE data production processing will commence as the validation phase nears completion. Correlative measurements collected by rockets, balloons, and aircraft flights, will continue to support NASA's earth atmosphere science, including results from ozone instruments aboard NOAA satellites.

NASA Aircraft Facilities

Refitting of the DC-8 acquired to replace the Convair 990 (destroyed in a runway accident in the summer of 1985) is progressing rapidly, and replacement of the Aircraft Quad-Polarization Synthetic Aperture Radar (SAR) will be partially completed by the end of 1987. We anticipate that the DC-8 may be flown to the Antarctic in late 1987/early 1988, to study the springtime depletion of stratospheric ozone that occurs there. The construction of a new aircraft instrument, the Airborne Visible-Infrared Imaging Spectrometer (AVIRIS) to be mounted on a NASA ER-2 jet, is scheduled for engineering flights in February 1987 and scientific test and calibration by April 1987. It will acquire multi-channel spectral data at high spatial and spectral resolution to provide data for detailed mapping of the composition of surface materials. AVIRIS is expected to operational for scientific data collection in the summer of 1987.

LIFE SCIENCES

In FY 1988, we are requesting $74.6 million for the Life Sciences Program, which is involved in nearly all aspects of space exploration, ranging from studies of the ability of humans to live and work in space to studies which examine the origin, evolution, and distribution of life in the universe. Last year we established a Task Force under the Chairmanship of Dr. Frederick Robbins, a Nobel Prize Laureate, to develop a strategic plan for Space Life Sciences.

While inflight research opportunities in 1986 were limited by the *Challenger* accident, a major investigation in neurophysiology was conducted by a U.S.-led team on the German D-1 Spacelab mission. This study clearly demonstrated the alterations in man's visual and vestibular interactions which occur during space flight. International cooperation emerged as one of our major activities during FY 1986. Formal Joint Life Sciences Program Working Groups were established with the European Space Agency, the Japanese, French, and Germans. These groups were organized to use the limited resources available to conduct space research in an efficient way to improve the science return in the Life Sciences and to allow the early formation of international scientific teams to address research problems during the space station era.

The FY 1988 budget request will support preparations for the Spacelab Life Sciences 1 (SLS-1) scheduled for launch during 1990. It will also support preparations for the first International Microgravity Laboratory (IML-1) mission, the Spacelab J mission with Japan, and the second dedicated Life Sciences Spacelab mission, Spacelab Life Sciences 2 (SLS-2). We will also continue to plan a research program for utilization of the Space Station, which will provide facilities for significant research in all areas of Life Science, particularly the investigation of continued and repeated long-term human exposure to the space environment.

NASA is continuing to investigate the nature and mechanisms of human physiological adaptation and deconditioning which occur during space flight. A Health Maintenance Facility, incorporating state-of-the-art technology, is being developed for the Space Station era. A new project concerned with the application of remote sensing technology to the solution of global health problems is being initiated. Definition of space station related facilities required for the wide range of life sciences activities is continuing.

SPACELAB PAYLOADS

Some significant Spacelab payload flight activities took place prior to the *Challenger* accident. In October 1985 *Spacelab D-1,* a reimbursable mission sponsored by the Federal Republic of Germany, which included several cooperative U.S. experiments and the Materials Science Laboratory (MSL) were successfully flown. Considerable progress was made on the analysis of scientific data from the Spacelab-2 and 3 missions in the fields of astronomy, solar physics, plasma physics, biology, materials processing, and atmospheric sciences.

However, the rest of 1986 was dominated by replanning and program streamlining activities in response to the *Challenger* accident. All planned Spacelab missions have been delayed an average of 3-4 years. Development and mission planning activities have been re-phased, and project teams have been scaled down accordingly. For FY 1988 we request $75.4 million to support our restructured Spacelab Payloads program. Planning continued for critical science missions as noted below.

Astro-1

The Astro payload will explore the universe by observing and measuring the ultraviolet radiation from celestial objects. Targets selected for Astro missions include planets, stars, star clusters, galaxies, clusters of galaxies, quasars, remnants of exploded stars, clouds of gas and dust, and the interstellar medium. Three instruments make up the Astro payload: the Hopkins Ultraviolet Telescope (HUT), the Ultraviolet Imaging Telescope (UIT), and the University of Wisconsin Ultraviolet Photopolarimetery Experiment (WUPPE). Astro will be flown twice in the early 1990's, with each mission lasting from seven to ten days. The ASTRO Mission was scheduled to be launched on the first Shuttle flight after the *Challenger* and hence is in an advanced stage of readiness for an early flight opportunity when Shuttle flights resume.

Shuttle High Energy Astrophysics Laboratory (SHEAL)

Work has continued on the development of two x-ray astronomy investigations to be flown on the SHEAL mission. One instrument, the Diffuse X-ray Spectrometer, will provide the first high-spectral-resolution survey of the million-degree gas in the space between the stars. The second instrument, the Broad Band X-Ray Telescope, will conduct high-sensitivity, moderate-spectral-resolution observations of a wide variety of cosmic x-ray sources. The first SHEAL mission is presently planned for late 1992.

Spacelab Life Science-1 (SLS-1)

SLS-1 is a high priority mission, which will gather data on the physiological effect of weightlessness on humans. It will provide important baseline data needed to enable long-term human presence in space. SLS-1 is scheduled for launch in December 1989, but an option to launch approximately 6 months earlier is being maintained.

International Microgravity Laboratory (IML-1)

IML-1, which is now scheduled for launch in April 1990, will include microgravity science and life science investigations involving over 150 scientists in the United States and 10 foreign countries. The IML series is based upon the concept of sharing U.S. and foreign flight hardware when appropriate to perform U.S. science, rather than to purchase or develop a replica for U.S. use.

Atmospheric Laboratory for Applications and Sciences-1 (ATLAS-1)

ATLAS-1 is scheduled for launch in January 1991. ATLAS-1, a partial payload, was derived from reconfiguring the Earth Observations Mission-½ and 3 in order to provide a more easily manifested payload. The Atlas-1 payload consists of both U.S. and foreign instruments.

Spacelab J

The Spacelab J mission is a shared-cargo mission with NASDA (Japan). Japan is proceeding with payload hardware development and testing to complete the major development effort in 1988. The NASA portion of the payload has the major development effort scheduled for FY 1988 and FY 1989 with a planned launch in May 1991.

Secondary Payloads

A modest level of development will continue on a number of smaller Shuttle attached missions supporting a variety of disciplines including materials processing, high energy astrophysics, solar physics, and atmospheric sciences. The launch status of these missions will be clarified once the manifesting of secondary payloads is addressed.

Airborne Science and Applications Program

The Airborne Science and Applications program aircraft flights will support various discipline investigations in FY 1988 including continued study of the Antactica ozone hole. The FY 1988 budget includes initial funding to acquire a new ER-2 high altitude aircraft to replace the two aging U-2C's for which DoD is discontinuing maintenance facilities. The new ER-2 will enhance the science payload capacity over that of the single ER-2 and the two U-2C's (which will be retired).

MICROGRAVITY SCIENCE AND APPLICATIONS

In FY 1988, we request $45.9 million for Microgravity Science and Applications. The goals of the program are: to conduct basic research on the effects of the reduced gravity environment of space; to understand the basic phenomena of physics, chemistry, and materials science; to apply the results of this research to develop practical applications; and, to provide for the wide dissemination of experimental results to the U.S. industrial, governmental, and academic communities. The program is structured in six major technical disciplines: metals and alloys, electronic materials, glasses and ceramics, biotechnology, combustion science, and fluid dynamics and transport phenomena.

During 1988, an active ground-based research program will be carried out. Due to the *Challenger* accident, there will be no flight opportunities in microgravity science and applications for about one year after the STS flights are resumed, seriously hampering our ability to obtain a long duration reduced gravity environment to perform experimental studies. The previously planned program was carefully reviewed to determine how to make the best use of the time and resources available until STS operation is reinitiated. As a result of this assessment, we are taking the following steps: (1) storing flight hardware; (2) slowing down the development of selected new space flight hardware to make its later delivery consistent with projected flight opportunities; and, (3) increasing emphasis on complementary research in ground-based laboratories and in the reduced gravity environments provided in our drop towers and aircraft.

Although we believe we can maintain a viable, high-quality program in the short term with this approach, there is no substitute for performing the required long-duration research in the reduced gravity environment of space. We can only develop the reduced-gravity scientific data base required by the scientific academic, and industrial communities through an aggressive research program aboard the Space Shuttle and eventually the Space Station.

The program challenge is to optimize the research we can conduct within flight opportunities provided by the projected Shuttle manifest and devise a strategy to provide increased resources and space flight research opportunities that are necessary. The FY 1988 request will also support a significant increase and acceleration in the design and development of microgravity science and application payloads for the Space Station.

In FY 1988, Microgravity Science and Applications ground-based research will continue in the universities, the Centers of Excellence, industry, and the NASA Centers.

We found five Centers of Excellence:

Institute for Theoretical Physics, University of California, Santa Barbara;

Bioprocessing and Pharmaceutical Research Center of Philadelphia, University City Science Center;

Center for Separation Science, University of Arizona;

Center for Microgravity Fluid Mechanics and Transport Phenomena, University of Colorado;

Materials Processing Center, Massachusetts Institute of Technology.

The Center for Microgravity Fluid Mechanics and Transport Phenomena at the University of Colorado was initiated during the past year. The ground-based research in total and the Centers of Excellence in particular serve as an important focus for new ideas and the dissemination of research opportunities and results.

During the Shuttle flight hiatus, we will encourage the use of the Microgravity Materials Science Laboratory (MMSL) located at the Lewis Research Center in Cleveland. The MMSL was created to provide an opportunity for academic, industry, and Government researchers to try out ideas on flight-type hardware. The reduced-gravity facilities, both ground-based (drop towers and drop tubes) and airborne (aircraft), will be utilized much more aggressively to compensate in part for the lack of space flight opportunities. Unfortunately, the short time duration of reduced gravity provided in these facilities limits the nature and scope of the research that can be conducted.

COMMUNICATIONS

In FY 1988, we request $20.5 million for the communications program. Activities include Technical Consultation, Experiment Coordination and Operations Support, and Research and Analysis. No funding is requested in FY 1988 for the Advanced Communications Technology Satellite (ACTS) Program, because it is the position of the Administration that development of this commercially-oriented technology should be left to the private sector.

Satellite-Aide Search and Rescue (SARSAT)

We request $1.3 million in FY 1988 to support system engineering and to develop new technologies for the Satellite-Aided Search and Rescue (SARSAT) Program. This international search-and-rescue system has already been credited with saving over 675 lives. Five satellites are now in service, two from the U.S. and three from the U.S.S.R. The current ground system consists of six mission control centers in the U.S., Canada, France, Norway, U.S.S.R. and Great Britain. Fourteen local user terminals will be in operation by the end of 1987.

During 1988, an experiment using geostationary satellites for more nearly instand alert will be completed and the results analyzed. Efforts will continue to improved the cost/performance ratio of emergency beacons.

Technical Consultation and Support Studies

We are requesting $3.4 million in FY 1988 for our Technical Consultation and Support Studies program, which provides the technical basis to develop national and international policies, regulations, and telecommunications standards to assure the orderly growth of both existing and new satellite services.

In 1986, we developed a geostationary orbit arc allotment concept as part of the U.S. preparations for the 1988 Space World Administrative Radio Conference (SWARC). This approach will further U.S. interests in retaining flexibility for U.S. communications satellite networks. During 1987, we will participate in the SWARC for mobile services to secure the new allocations for international mobile satellite operation. In 1988 we will complete work on the geostationary orbit arc allotment planning method and provide key support at the second session of the SWARC, and will continue to develop techniques to maximize use of the limited resources of orbital arc and radio spectrum.

The FY 1988 request will support continued operation of the Applications Technology Satellite (ATS) spacecraft, which continues to provide vital support to the National Science Foundation, NOAA, DOD, DOI, the DEA, a number of universities, and state and local governments, and domestic and international disaster relief organizations. Support is provided through satellite voice and data links for science, education, disaster relief, and communications applications experiments to North and South America, most of the eastern Pacific Ocean, Hawaii, and Antarctica.

Research and Analysis

Our efforts in communications research during FY 1988 will focus on future high risk microwave and optical technology needed to increase the capacity and interconnectivity of future communications satellite systems to provide information services at lower costs to smaller terminals for both fixed and mobile applications. The Mobile Satellite Technology Experiment program will develop, build, and test critical technologies for this new service in cooperation with industry and government agency users. The recent approval by the FCC of frequencies for a domestic mobile satellite service has removed a major roadlock to system implementation. In 1986, we completed our system design studies and initiated hardware development. Field tests of some hardware will be conducted in 1987. In 1988, all prototype components will be completed and field testing of the full mobile terminal will begin.

INFORMATION SYSTEMS

For FY 1988, we are requesting $22.3 million for our multidisciplinary Information Systems program. This program supports Space Science and Applications flight projects and science programs in three ways: (1) by managing major NASA computational resources, (2) by working with discipine programs to establish discipline data centers to help NASA scientists locate, access and utilize data needed for research, and (3) by developing the advanced networks and computing technologies needed to efficiently handle the massive amounts of data acquired from successful space missions.

Several major data processing systems used by researchers to make large-scale computations and to test complex scientific models are located at the Goddard Space Flight Center (GSFC). These include the large-scale IBM, CDC, and AMDHAL computers in our Space and Earth Science Computing Center (SESCC). In addition, the program is responsible for the National Space Science Data Center (NSSDC), which is the hub of a nation-wide network for NASA-acquired data. This network ensures the widespread availability of data from NASA's satellites and rocket flights.

In FY 1987, we begun implementing a master directory for all NASA-acquired data at the NSSDC, and established nationwide electronic access to catalogs at our distributed discipline data centers. Through our "pilot" data systems program, we develop new capabilities to access and manage data for the oceans, planetary, and climate disciplines. The successful demonstration of networks, optical disks and other technologies in one science discipline facilitates their adaptation by other disciplines and flight missions. Like the NASA Ocean Data System in FY 1986, our Planetary Data System (PDS) has been integrated into its client discipline program. The Planetary Research program will use the PDS as the nucleus for a future planetary data network.

In FY 1988, we will continue to develop improved capabiliites to manage and distribute space data. We intend to emphasize improved network access to NASA data, develop common catalogs and data standards, and interdisciplinary data systems for planned Space Station platforms. We will help to develop information systems for long-term interdisciplinary flight missions, which includes integrating widely separated data centers into a unified information network to support interdisciplinary research. Such a unified data management capability will be needed by all Space Science and Applications programs and flight projects in the 1990s, especially for major missions such as the planned Earth Observing System (EOS) mission, if approved.

We will continue in FY 1988 to work with NOAA, USGA, and NSF in areas such as networking and supercomputer applications and will provide technical consultation in key areas, such as Earth science, planetary science, astrophysics, and Space Station studies.

SPACE STATION

The Office of Space Science and Applications (OSSA) plans to be a user of the unique resources offered by both the space and ground elements of the Space Station Program. We visualize the Space station as a NASA laboratory in space, working with our established ground laboratories, such as the Goddard Space Flight Center and the Jet Propulsion Laboratory. Our interests include in-orbit servicing of on-board experients and free-flying spacecraft, polar and co-orbiting platforms to conduct major future scientific missions (such as the EOS and AXAF), pressurized modules for microgravity and life sciences research, and facilities for attached payloads. We will also continue to utilize sounding rockets, ELVs, Shuttle, Shuttle-Spacelab, umanned platforms, and other available systems to support science and applications objectives.

OSSA took several significant steps in 1986 to prepare for the Space Station. An integration function was established to focus activities related to the Space Station. We will continue to develop consolidated plans with the discipline divisions, and provide technial support for the conduct and management of multi-discipline studies related to use of the Space Station.

IN 1986 OSSA participated in the Space Station configuration and assembly reassessment study with the Operations Task Force. The reassessment study responded to needs identified within NASA as a result of the *Challenger* accident; it also addressed Congressional concerns that the Space Station Program provide useful scientific research as early as possible during the flight operations phase. Our efforts focused on identifying possible ways in which experiment facilities in the assembled flight elements could be outfitted to perform useful scientific research prior to the completion of the entire assembly sequence.

To support the Operation Task Force, a Science Operations Task Team was established to develop a science operations concept and plan. Space Station will provide researchers with the capability to conduct experiments in space and from their own ground-based laboratories. This capability, called "telescience," a concept developed by our advisory Task Force on the Scienfic Uses of the Space Station (TFSUSS), is a major science operations goal for the Space Station era. We are working on a structure to continue to provide this type of professional consultation from the experts in academia and private industry, probably under the aegis of the NASA Advisory Council.

We also initiated a number of technical studies to assure early science benefits from the Space Station. The Pressurized Volume Utilization study is being conducted to establish a baseline plan for outfitting pressurized modules for maximum use by all user groups and disciplines. Other studies examined issues of contamination, waste disposal and logistics and supply. These studies will help the science disciplines define parameters of payloads and experiments and understand how they will be influenced by the Space Station environment.

We envision extensive use of the Space Station to further our scientific programs. In Astrophysics the most important capability that the Space Station can provide is the servicing of orbiting spacecraft and instruments. Other priorities include co-orbiting platforms which could be used to complete our program of Great Observatories if approved in a future budget, first with the planned Advanced X-ray Astrophysics Facility (AXAF) and then with the Space Infrared Telescope Facility (SIRFT). Potential attached payloads could include the High Resolution Solar Observatory (HRSO) if approved in a future budget, a Cosmic Ray Nuclei Experiment (CRNE) as a follow-on to the one conducted on the Spacelab 2 mission in 1985, and low-cost Spartan payloads similar to those launched and retrieved during Space Shuttle missions.

In the Earth Sciences, a yet to be approved Earth Observing System (Eos) is being discussed for possible deployment on the poar platforms to be furnished as part of the Space Station program by both NASA and ESA.

In Planetary Exploration, the major emphasis for near-term Space Station activities is the potential development, if approved, of two important attached payloads to support planetary research: the Astrometric Telescope Facility (ATF) and the Cosmic Dust Collector Facility (CDCF). AFT will address an important and long-desired goal: the search for other planets around nearby stars. By making precise, long-term measurements of the motions of stars, ATF can detect the presence of planets as small as Uranus or Neptune around them. The CDCF will collect tiny particles of interplanetary and perhaps interstellar dust. Returned to Earth, and analyzed in detail, these particles can provide unique and fundamental information about chemical processes in the early solar system and perhaps in interstellar space.

The Space Station will be a critical base for research in the Earth sciences, life sciences and microgravity sciences as earlier described. In short, we are depending on Space Station to be the core for an aggressive and far ranging space science and applications program in the 1990's and beyond. We are working closely with all parties involved to ensure that the science return from the Space Station is commensurate with our National investment.

SUPPORTING PROGRAMS

Supporting programs in Suborbital Research and in ground-based Research and Analysis are an essential complement for all Space Science and Applications flight mission activities. Our research and analysis activities were briefly discussed earlier. The importance of the suborbital program is underscored by the hiatus in Shuttle flights. Suborbital flights of balloons, aircraft, and sounding rockets provide observations that complement the results of more complex orbital missions and also facilitate the development and testing of instruments that will eventually make orbital observations.

The Research and Analysis program provides even more diverse and essential science support functions: theoretical studies, laboratory research, advanced technology and mission definition, ground-based observations to support flight missions, and extended analyses of data from completed missions. These supporting programs are a significant fraction of the basic research support to the university, government, and industrial scientific researchers, who are the core of the Space Science and Applications Program.

Continuing problems with our heavy-lift balloons led to the development and selection of a new, balloon-quality, polyethylene film (Raven Astrofilm-E) during 1986. Also in 1986, we successfully launched 26 balloons (out of 36 attempts) to support observations in upper atmosphere science, astrophysical research, and solar physics. A total of 49 flights are planned for 1987, including test flights to qualify balloons for heavier payloads (5,000 to 6,000 pounds), launches of heavy payloads from the semi-permanent launch site at Fort Sumner, New Mexico, transglobal flights starting from Alice Springs, Australia, and a major expedition to Canada.

The sounding rocket program achieved 31 successes (out of 33 attempts) in 1986 to support studies in astronomy, solar and planetary physics, plasma physics, and upper atmospheric physics. The program will be expanded to about 40 launches per year in 1987 and 1988 to ease the impact on scientists whose experiments are grounded until the Space Shuttle resumes flight operations. A major activity early in 1987 will be a series of sounding rocket launches, including eight NASA payloads, from a mobile launch facility that will be sent to Greenland for studies of winter polar cap turbulence, electric fields over the aurora, and disturbed thermospheric winds.

The Kuiper Airborne Observatory (KAO), a C-141 aircraft equipped with a 91-centimeter telescope, is able to make astronomical observations above 91 percent of the Earth's atmosphere. The KAO is scheduled to make 72 research flights in FY 1987, permitting 29 groups of scientists to make measurements in the near-infrared and sub-millimeter wavelength spectral regions.

In our Research and Analysis program noted earlier in the discipline narratives, a major achievement during 1986 was the result of long-term studies of the positions and velocities of galaxies by Dr. Margaret Geller of Harvard University. Her findings are giving us a new picture of the universe, one in which galaxies seem to form along the surfaces described as immense "bubbles" in intergalactic space rather than being evenly distributed.

POTENTIAL FUTURE MISSIONS

The Space Science and Applications program continues to support advanced studies of possible future missions in order to define, select, and plan missions that are both scientifically exciting and cost-effective. Our efforts in Advanced Technology

Development (ATD) for potential future missions have resulted in significant returns for other missions. To demonstrate this point OSSA commissioned a Technology Development Study to review the technological developments from two of our most important approved missions—the Hubble Space Telescope (HST) and *Galileo*. The study was conducted to give greater recognition to the outstanding technology that results from our space science missions. These ATD activities are clearly contributing to U.S. technological leadership, and should be recognized as such. Our advanced studies for potential future missions have a significant return, not only for space science and applications, but also for many other scientific endeavors. The survey focused on hardward and software technology developed over each project's life-cycle covering the period from pre-project approval through integration and test.

Data collected from interviews, questionnaires, and technical publications resulted in over 100 *Galileo* and HST technology developments being identified and documented. Of those identified, 42 were categorized as outstanding or significant, according to criteria established in the study. The survey also identified more than 100 resulting publications, helping NASA to disseminate this valuable information on NASA-developed technology.

Contributions to future scientific missions include an expanded and computerized guide star catalogue, significant advancement in fabrication of large systems, high resolution optics, and improved detectors. Other contributions to future NASA missions inlcude advancements in radiation hardened electronics, software development and extensive advancements in contamination control procedures. Several of the technology items developed for NASA's *Galileo* and HST missions have also contributed to commercial applications. Examples from *Galileo* include a minaturized turbine pump and charge coupled devices now being utilized in solid-state automatic cameras. The study clearly demonstrates that our moderate investment in the development of advanced technology not only assures our technical readiness to implement missions, when approved, with lower risk, but also provides new technology with potential applications in other areas.

I would like to describe briefly some of the more exciting candidate missions for the future.

Astrophysics

The main thrust of our future missions in space astronomy is to make available four Great Observatories to study the universe across the entire electromagnetic spectrum. Two potential new programs will complete this effort: the Advanced X-ray Astrophysics Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF). Another future mission under consideration is planned to test Einstein's General Theory of Relativity.

The third of the four Great Observatories, AXAF will use a nested array of six pairs of mirrors with a 10-meter focal length to improve observational resolution and sensitivity in the X-ray region by a factor of 100 or more. These observations are of interest to a broad range of the scientific community because they promise new information on the birth and death of stars, and the nature of quasars, pulsars, neutron stars and black holes. Two contractors, Lockheed and TRW, have completed parallel definition studies with the goal of being ready for flight in the mid-1990's.

The last of the four Great Observatories will be SIRTF, an observatory for infrared astronomy that will use long mission life, precision cryogenic optics, and dramatic increases in the state of the art in detectors to give astronomers 1,000 times greater sensitivity than its predecessor, IRAS. In 1987 studies of detector technology, instruments concepts, and mission options continue. We hope to launch SIRTF in the late 1990s to complete the Great Observatories program.

Planetary Exploration

Studies of future planetary missions are being carried out in more detall to expand the exploration concept recommended by the Solar System Exploration Committee (SSEC): a "Core Program" of exciting, cost-effective Planetary Observer and Mariner Mark II missions (to the inner and outer regions, respectively, of the solar system), to which are added major Augmentation Missions involving both high science yield and significant technical challenge.

Currently, the primary focus of this activity is the *Comet* Rendezvous/Asteroid Flyby (CRAF) mission proposed to be the first project for the new Mariner Mark II spacecraft. This mission, after a close encounter with an asteroid, will rendezvous with a comet and fly tandem with it in order to study directly the comet nucleus and observe the dynamic behavior of a comet (both its nucleus and coma) over a period of several years. Late in 1986, the mission science payload was selected for the CRAF mission (now named Mariner Tempel 2). This group of exciting investigations includes a penetrator that will be shot from the spacecraft into the nucleus of the comet to obtain the first direct information about the nature, organic and inorganic materials, and the ices that comprise the comet's nucleus.

During 1988, studies of the Mariner Tempel 2 mission will be carried forward in more detail. In addition, several other missions in the "Core Program" will be studied. These include Lunar Geoscience Observer, a mission to globally map the Moon and to study its potential resources, Near-Earth Asteroid Rendezvous Observer, a mission to undertake the first long-term encounter with an asteroid, and a Saturn Orbiter/Titan Probe mission that would make a long-term study of Saturn and probe the atmosphere and surface of its giant moon Titan. This latter mission, called Cassini, is now being studied as a possible NASA-ESA cooperative project.

In addition, studies of two possible Augmentation Missions will be expanded: a Mars Surface Sample Return and a Comet Nucleus Sample Return. Both of these missions would produce a major increase in our understanding of these bodies by returning samples to Earth for analysis in terrestrial laboratories.

CONCLUSION

The FY 1988 budget request will provide for continued progress in the space science and applications disciplines. It will support our efforts to maintain the momentum of our past achievements, and it will ensure the readiness of approved missions for the resumption of Space Shuttle flights. It will also ensure that we are ready to make full use of the unique capabilities of the Space Station. This budget request will also support, through the "Vitality Program", our efforts to preserve and maintain the science research base that is critical to maintaining U.S. leadership in space.

Thank you.

OFFICE OF SPACE SCIENCE AND APPLICATIONS, FISCAL YEAR 1988 BUDGET REQUEST

[In millions of dollars]

	Fiscal year—		
	1986 budget	1987 budget	1988 budget
Physics and astronomy—total	569.3	552.8	567.1
Hubble space telescope development	125.8	101.3	98.4
Gamma ray observatory development	85.3	50.5	49.1
Spacelab payload development and mission management	79.4	74.6	75.4
Space station payload and planning		15.5	29.0
Explorer development	48.2	56.7	60.3
Mission operations and data analysis	111.7	125.7	128.1
Research and analysis	49.0	53.4	60.1
Suborbital programs	69.9	75.1	75.7
Planetary exploration—total	353.6	358.4	307.3
Galileo development	64.2	71.2	55.3
Ulysses	8.8	10.3	10.8
Magellan	120.3	92.6	59.6
Mars observer	33.8	35.8	29.3
Mission operations and data analysis	67.0	80.0	77.0
Research and analysis	59.5	68.5	75.3
Life sciences—total	66.1	72.2	74.6
Flight experiments	32.1	30.4	32.9
Research and analysis	34.0	41.8	41.7
Space applications	487.5	569.3	559.3
Solid Earth Observation:			
Shuttle payloads	21.8	21.6	21.1
Geodynamics	30.0	32.1	33.1
Research and analysis	19.1	21.9	22.6
Subtotal	70.9	75.6	76.8
Environmental observations:			
Interdisciplinary research and analysis	1.0	1.1	1.1
Upper atmosphere research and analysis	31.1	33.4	34.4
Oceanic processes research and analysis	17.4	20.8	21.5
Atmospheric dynamics/radiation research and analysis	28.7	31.9	32.9
Space physics research and analysis	16.8	21.0	21.5

OFFICE OF SPACE SCIENCE AND APPLICATIONS, FISCAL YEAR 1988 BUDGET REQUEST—Continued

[In millions of dollars]

	Fiscal year—		
	1986 budget	1987 budget	1988 budget
Shuttle payloads	5.3	12.0	19.4
Tether payloads	6.4	1.0	3.1
Earth radiation budget experiment	1.9		
Mission operations and data analysis	35.0	33.6	26.8
Upper atmosphere research satellite mission	114.0	114.2	95.4
Scatterometer	14.0	32.9	22.7
Ocean topography experiment		19.0	90.0
Global geospace science			25.0
Subtotal	271.6	320.9	393.8
Materials processing in space:			
Research and analysis	12.1	13.9	14.4
Materials experiment operations	18.9	34.0	31.5
Subtotal	31.0	47.9	45.9
Communications:			
Research and analysis	9.8	13.0	14.4
Search and rescue	1.1	1.0	1.3
Technical consultation and support	2.5	3.2	3.4
Experiment coordination and operation support	1.1	1.3	1.4
Advanced Communications Technology Satellite	81.9	85.0	
Subtotal	96.4	103.5	20.5
Information systems	17.6	21.3	22.3
Total, Office of Space Science and Applications	1476.5.	1552.6	1508.3

[The following information was subsequently received for the record:]

Written questions submitted by Senator Inouye.

Space Science and Applications

Question 1: Dr. Edelson, is it your opinion that NASA has a role in providing transitional support to the commercial sector to promote a commercial launch program? If so, what can NASA do to provide assistance to the commercial sector?

Answer 1: Yes, I feel that NASA should facilitate the commercial sector's efforts to establish a commercial launch program, consistent with that delineated in the Commercial Space Launch Act. Specifically, NASA should make available, where possible, those facilities and equipment necessary to the establishment of a commercial launch program.

Question 2: Do you think that a commercial launch site is needed to enhance U.S. competitiveness in its space science and applications program?

Answer 2: No, I do not feel that a separate commercial launch site is warranted or needed. Rather, I believe that the multi-purpose use of existing and future launch sites is the most cost effective approach for all parties at this time. A formal agreement has been reached between NASA and Space Services, Inc. allowing the commercial use of the Wallops Island launch site. Likewise, an agreement with General Dynamics allowing the use of NASA launch sites is nearing finalization and negotiations of a similar nature are underway with McDonnell Douglas.

I do not believe that the question of commercial launch site bears directly on U.S. competitiveness in its space science and applications program.

Responses to Written Questions Submitted by Senator Pressler.

Overall Space Science & Applications Budget

Question 1: While I recognize that one cannot completely assess the adequacy of a budget by the "bottom line" alone, I am struck by the fact that the total Space Science & Applications budget request for FY 1988 is $44 million less than the FY 1987 appropriation.

a. To what extent does this overall reduction affect adversely your programs, and does this reduction only establish a lower base from which future Space Science & Applications budgets will be determined?

b. Where in the FY 1988 request is the Space Science and Applications budget the "thinnest"?

Answer 1a: The reduction of $44 million in the OSSA budget for FY 1988 below the FY 1987 level is the result of many project-related changes in funding reflecting the turn-down in development of some flight projects (e.g., Galileo, Magellan, and UARS), as well as increases in programs in their early development cycles (e.g., TOPEX and GGS). In addition, the rescission action proposed for ACTS in FY 1987 results in no funding for this project in FY 1988. Most level-of-effort-activities in the OSSA budget are being continued at their ongoing rate from FY 1987 to FY 1988 with some growth in specific areas. OSSA will strive to maintain funding for the "research base" which is critical to the long-term conduct of the science and applications program.

b. As noted above, no FY 1988 funding is requested for the ACTS project, yet development continues consistent with the FY 1987 operating plan. This, by definition, is our "thinnest" budget. In addition, the combined effects of the Gramm-Rudman-Hollings reductions a year ago and the reprogramming actions required following the Challenger accident have reduced OSSA's normal flexibility for resolving technical and schedule issues on the major OSSA flight projects.

Question 2: The Space and Earth Science Advisory Committee (SESAC) report entitled "The Crisis in Space and Earth Science" asks the question, "Just how broad a Space Science and Applications (program) do we want and are prepared to support?"

While I believe that each of us today would delight in providing all the resources required to do well all of the science and applications endeavors we have started or expect to start in the near future, this may be a politically difficult solution to the problem. The SEASAC report's other alternative to the question is that we may have to be more selective in the things we choose to do--that we will have to establish priorities that may result in the termination of certain programs.

Could you comment on this second alternative--is it politically feasible, what would be the implications of terminating certain programs, or should we expect to do all things well?

Answer 2: For many years the NASA Office of Space Science and Applications has attempted to support a very broad program not only because there were important new activities to be carried out in individual disciplines but also because it was becoming increasingly apparent that there were interconnections between these disciplines. For example, global monitoring of changes in the Earth's environment involves multidisciplinary studies in geophysics and global biology; planetary exploration studies are tied to analog studies of processes occurring on or within the Earth; cosmic dust collection has implications for both solar system origin and exobiology; studies of physiological responses of humans to long duration exposure in the microgravity and radiation environment of space has implications for deep space travel, for servicing and repair of freeflying spacecraft or platforms at a Space Station, and for use of astronaut/scientists as investigators in space; studies of the plasma environment of space relate to studies of generation of the solar wind, energy deposition in the Earth's climate system, and the nature of planetary magnetic fields; and so on. Thus, changes or restrictions of research in one discipline often impact and can hinder several other areas of research as well. We agree with the Space and Earth Science Advisory Committee (SESAC) report that making such choices between competing, yet synergistic, disciplines would be wide ranging in impact and is also likely to be politically very difficult. We further agree that any decision to restrict research or choose between programs should be made on the basis of the widest possible discussion, not only in Congress but within the Executive Branch and the scientific community as well.

Mixed Fleet

Question 3: Could you tell us the number of Space Science & Applications payloads that have contributed to the total backlog of payloads, as a result of the Challenger accident?

As a result of the Challenger accident, what Space Science & Applications missions or payloads have been terminated?

What factors determined the termination of these payloads?

Answer 3: Prior to the Challenger accident, OSSA planning was based on an expectation of 75 equivalent Shuttle flights from FY 1986 through FY 1995. In response to the accident, the OSSA program was restructured and payloads included in the current planning baseline equate to approximately 38 equivalent Shuttle flights. Missions removed from the OSSA planning baseline are primarily from the attached payloads areas and include Spacelab missions, Material Science Laboratories (MSLs), and Spartans. The major consideration in the selection of these payloads was a distribution of the impact amongst the different discipline areas and an attempt to preserve initial flight opportunities for as many programs as possible at the expense of payload reflights.

Question 4: You mentioned in your opening statement that NASA had purchased a Delta ELV to launch the Cosmic Background Explorer (COBE) in 1989.

What other science and applications payloads are the highest priority candidates for an ELV launch, and which ELVs would best serve each of these individual payloads?

Given a Shuttle flight rate that may ramp up to 12 to 16 flights per year in 1993, how many ELVs are required through 1995 for science and applications payloads?

Answer 4: We have identified a total of 8 currently budgeted spacecraft (in addition to COBE) which we feel could be launched on ELVs. They are as follows:

Spacecraft	Launch Date	ELV Type
ROSAT	1990	Delta II
EUVE	1991	Delta
Mars Observer	1992	Titan III/TOS
Geotail	1992	Delta/PAM
WIND	1992	Delta/PAM
POLAR	1992	Delta/PAM
Cluster	1994	Delta/PAM
SOHO	1994	Titan III/AMS

In addition a Titan IV could be procured to serve as a backup for the Magellan, Ulysses, and Galileo missions, all of which are planned for Shuttle launch. The cost to acquire the ELVs, modify the spacecraft where required, and implement schedule adjustments has not been included in the FY 1988 budget.

Question 5: If ELV services are procured for science and applications payloads, from which budget will these funds come--that of Space Flight or that of Space Science and Applications?

Answer 5: A final determination has not been made but the basic philosophy is that budget control should reside with the responsible management organization, in this case OSF.

Question 6. What would be the effect on the Space Science & Applications programs if no ELV services were procured?

Answer 6: The flexibility to launch approved and planned science missions would be seriously impaired by exclusive reliance on the STS in the future.

Planetary Exploration Missions

Question 7: According to your testimony, the Mars Observer mission is planned for a 1992 launch. Yet, I understand that NASA is considering the procurement of an ELV for one or more of these missions.

Could you comment on NASA's position regarding the launch of the Mars Observer, Galileo, Ulysses, and Magellan missions?

Answer 7: Following the Space Shuttle Challenger accident, NASA had to review the priorities of its now extensive payloads backlog. The needs of the science community, commercial customers, international commitments and the Department of Defense had to be considered.

In addition to the Mars Observer, NASA has three other approved planetary missions:

Magellan - mission to map the surface of Venus - scheduled for 1988, now scheduled in 1989

Galileo - exploration of Jupiter - scheduled for 1986, now scheduled in the 1989-1991 timeframe

Ulysses - a joint mission of NASA and the European Space Agency to study the sun - scheduled for 1986, now scheduled in the 1989-1990 timeframe

The use of a Titan IV for launch of either Galileo, Ulysses or Magellan has been examined as well. Although the performance margin is adequate for each of these missions and would relieve the Shuttle of a dedicated planetary mission, the availability of a Titan IV in the 1989-90 time frame is questionable.

In view of the fact that the Shuttle manifest currently allows for only three planetary launch opportunities in the 1989-90 timeframe, a decision was made to slip Mars Observer to the next launch window in 1992 since it was in the earliest stages of development and would therefore be impacted the least by a launch delay.

Question 8: What would be the costs associated with a 1990 launch of the Mars Observer on a Titan 34D ELV compared to a 1992 launch on the Shuttle?

Does either mode of launch improve over the other the performance of the mission, in terms of longevity or scientific return?

Answer 8: Our current estimate of net costs for launching the Mars Observer Mission on a Titan 3 ELV is an increase of about $26 million. There would be an approximately $70 million savings on the spacecraft development by avoiding the two-year delay, which would roughly be offset by the cost of the Titan vehicle hardware that would be on the order of $74 million. There would, however, be an increase in cost as a result of the need to integrate the TOS upper stage with the Titan, which is estimated to cost about $24 million. It should be noted that costs would be increased in the near term (FY 1987 and FY 1988) due to the schedule acceleration, but would be offset in later years. There is a potential benefit in terms of longevity to the Titan launch because it would permit filling the spacecraft attitude control bi-propellant tanks to their full capacity. To do so for the shuttle would violate a launch constraint.

Question 9: If a decision were made to launch the Mars Observer in 1990, would your FY 1987 appropriation and your FY 1988 request be adequate? If not, what augmentations would be required?

Answer 9: If we were to launch the Mars Observer in 1990, our FY 1987 appropriation and FY 1988 request would not be adequate. An additional $20 million would be required in FY 1987 and an additional $55 million would be required in FY 1988 not including the cost of the Titan vehicle and upper stage integration. However, the agency has determined that the current budget cannot accommodate this increase without a significant impact to other program(s).

Question 10: Obviously, NASA still must decide whether it launches Galileo or Ulysses on the Shuttle in 1989.

What factors will determine this decision?

What advantages does the Shuttle launch in 1989 of one mission have over the other in terms of total programmatic costs and return of scientific data?

Since the Ulysses spacecraft is, in fact, a European Space Agency (ESA) spacecraft, what are the international considerations in deciding the launch date of Galileo and Ulysses?

Answer 10: The major factors affecting this decision are programmatic costs, data return issues, mission duration and quality of launch opportunity, personnel and skill mix considerations and international commitments.

In terms of programmatic costs and scientific data issues it is advantageous to launch Galileo in 1989. The cost saving of launching Galileo first is approximately $100-130 million. If Galileo is launched first, the prime Ulysses data return is still one year ahead of the prime Galileo data return. If Ulysses is launched first, the Ulysses data return is four years ahead of Galileo. Also, if Galileo is launched first, completion of both missions will be two years earlier than if Ulysses launches first.

The major international consideration in deciding the launch date of Galileo and Ulysses is the effect of the decision on the NASA-ESA relationship and its effect on future cooperative programs. NASA and ESA announced on April 3, 1987, a decision to launch Ulysses in 1990 and Galileo in 1989.

Question 11: What considerations have been given to launching one of the other three planetary missions--Galileo, Ulysses, or Magellan--on a Titan IV ELV, thereby freeing up a 1990 Shuttle launch opportunity for the Mars Observer?

What flexibility is there in the launch of these other three planetary missions?

Answer 11: NASA has studied the adaptability of the Galileo, Ulysses, and Magellan missions to launching by a Titan IV ELV and found that it is technically feasible in all three cases. The chief obstacle to such a plan is availability of a Titan IV for NASA in 1989 or 1990.

Question 12: If NASA does not resume Shuttle flights in February 1988, as targeted, how will this delay affect the launch of the planetary missions, or, put another way, how much of a delay beyond February 1988 can the planetary missions tolerate before the delay affects their currently scheduled launches?

Answer 12: NASA has initiated a detailed contingency analysis of the decision that will be necessary should the current manifest of STS flights be delayed. Any delay of more than six months would probably jeopardize planetary launch schedule although planetary missions are accorded high priority level on recognition of the constraint of narrow launch windows.

Advanced Communications Technology Satellite (ACTS) Program

Question 13: According to your statement, the Administration requested no funds for the ACTS program because this development should be left to the private sector.

What is NASA's position, or your position for that matter, on the appropriate role of the government in the ACTS program?

Answer 13: Since 1986, Administration policy has been that the development of commercially oriented space communications technology should be left to the private sector.

Question 14: What evidence is there that the private sector would develop the ACTS program?

Answer 14: There has been no specific evidence of U.S. industry willingness to fund development of ACTS technology. In 1983 there was a proposal from Hughes Aerospace to develop and demonstrate an advanced communications technology; however, it did not include several technological developments central to the NASA ACTS capabilities, among them: hopping spot beam capability, space-based switching functions, and the direct detection laser transmission reception.

Question 15: Assuming that the Administration's request to rescind the unspent FY 1987 ACTS funds is not approved, how much will NASA have spent on ACTS through FY 1987?

How many experiments and at what dollar value has the private sector developed for the ACTS program through FY 1987?

Answer 15a: NASA will have spent $45 million in pre-project funds and $237 million in ACTS development funds.

Answer 15b: The major ACTS contractors/subcontractors (RCA, TRW, Motorola, Comsat) have invested $130 million in ACTS technology development, hardware, ground facilities and experiments. Further, other industry contributions have been made in the form of reduced government expense, such as billing the agency only for the recurring cost of the RCA spacecraft bus (not design/development costs), and other contractors' fee reductions. Currently, over 90 U.S. organizations have indicated they intend to experiment with ACTS over the 2+ years of analysis. Our rough estimate of experimenter costs is on the order of $30 million. It is expected that many industry-sponsored experimenters may provide their own ground facilities as well; however, the number and magnitude of this investment is proprietary to them.

Question 16: How and to what extent would ACTS-developed technology benefit or enhance future space station communications capabilities?

Without revealing proprietary information, to what extent will the ACTS program benefit our national security interests, and what budgetary support for the ACTS program has DOD provided to date?

Answer 16a: The hopping spot beams, space-based switching, and laser intersatellite link technologies being developed on ACTS will allow multiple very high definition television (VHDTV) transmissions from the space station and its co-orbiting platforms to anywhere on earth.

Answer 16b: The Air Force Space Division has funded a Laser experiment on ACTS expected to cost approximately $75 million dollars. In addition, other DOD experiments are planned for ACTS.

Question 17: The FY 1987 funding of $85 million for ACTS is based on a launch-readiness in 1990.

What FY 1988 funding is required to maintain this schedule?

Answer 17: The funding plan in FY 1988 for a 1990 launch readiness is $70 million, but the program is under review and is not currently manifested.

Use of Radioisotope Thermoelectric Generators (RTG's)

Question 18: What progress has been made in the interagency review of the use of RTGs on the Galileo and Ulysses missions, and when is a final decision expected?

Answer 18: The interagency review process for a NASA mission consists of two parts: a safety analysis conducted by the DOE for NASA which results in a Final Safety Analysis Report (FSAR); then, an independent evaluation of the safety analysis is conducted by the safety organizations of the three agencies, (DOD, DOE, NASA), coordinated by the Interagency Nuclear Safety Review Panel (INSRP), and results in a Safety Evaluation Report (SER). The DOE expects to begin the Safety Analysis this Spring; the Safety Evaluation will begin in the Fall of 1988 for the launch opportunities in the Fall of 1989. Given the completed FSAR and SER, the Administrator will consult with the heads of DoD and DoE and request launch approval from OSTP during the Summer of 1989.

Question 19: What decision has been made concerning the use of additional shielding to surround the RTGs and what factors have influenced this decision?

Would shielding be required if either one of these two missions were to be launched by a Titan IV ELV?

Answer 19: NASA has concluded that insufficient basis exists for altering the baseline plan for the Galileo (GLL) and Ulysses (ULS) missions. The baseline plan calls for adding no incremental shielding beyond that which is already incorporated in the RTG's basic design. That basic design already includes fuel containment, impact-attenuation and reentry ablation elements.

NASA considered the use of incremental protection for the RTGs in the STS/inertial upper stage (IUS) configuration. The analysis indicated that a full-enclosure container could offer some incremental protection during launch ascent phases, but could also lead to increased local release in the event of an unplanned reentry. For in an unplanned reentry, if one were not able to jettison the full-enclosure device, it could compromise the safety factors inherent in the basic design.

NASA assessment is that shielding would also not be required if either mission were to be launched on an ELV.

Question 20: What concerns exist about the life of plutonium fuel source in the RTGs -- under what circumstances might the fuel source expire before the planned completion of the mission?

Answer 20: The decay of the Plutonium fuel source (with a half-life of 86 years) causes the RTG power output to decrease with time. Based on periodic tests of the power output of the Galileo and Ulysses RTGs, we have determined that adequate power is available for a Galileo launch in 1989, and with the addition of a battery, for a launch in 1991. The RTG power is also adequate for Ulysses launches in 1989 and 1990. For the Ulysses 1991 launch opportunity, the RTG can be used but some instrument power cycling would be required. For launch opportunities beyond 1991, the RTGs for both missions would require refueling.

Question 21: If the interagency review of the use of RTGs led to a disapproval of the use of RTGs on the Galileo or Ulysses missions, what options would then exist for the launch of these two missions?

Answer 21: In the unlikely event that the use of RTGs on the Galileo and Ulysses missions on the Shuttle/IUS is disapproved, the only alternative would be to seek approval for launch on an expendable launch vehicle, i.e. TITAN IV. There is currently no practical alternative to the use of RTGs to explore the outer planets.

Spacelab

Question 22: It is my understanding that NASA is cancelling up to 15 Shuttle Spacelab missions during the next five years.

Is this correct, and, if so, approximately how many Spacelab missions will fly on the Shuttle during the next five years?

What are the implications of this reduced Spacelab activity for both domestic and international space science activities?

What is being done to compensate for this ~~a~~effect?

Answer 22: It is true that on the order of 15 Spacelab missions have been cancelled. However, it should be pointed out that most of these missions fall in the reflight category and that at least the initial flights in the major Spacelab flight series have been preserved although substantially delayed. If additional flight opportunities were to materialize, it would be rather simple to reinstate many of the reflight missions. The October 1986 manifest includes a total of 4 Spacelab missions in the next five years, 2 dedicated module missions, and 2 partial payload pallet missions.

The reduction in Spacelab activity has produced major impact to space science teams throughout the world. Almost without exception, the sponsoring institutions have chosen to continue their involvement with Spacelab and we have attempted to maintain and support core capabilities of the science teams. We continue to explore technical alternatives to enhance the manifesting flexibility of Spacelab payloads and we are assessing the suitability of many Spacelab payloads for Space Station applications.

For the Spartan program in particular, we are evaluating the extent to which sounding rockets and high altitude balloon flights might be used to accommodate planned science investigations. We expect to develop an overall strategy on this matter over the next several months.

Hubble Space Telescope

Question 23: I understand that the Hubble Space Telescope is experiencing some power problems.

What is the nature of these problems, and can they be corrected before the scheduled Shuttle launch in November 1988? What are the costs of correcting these power problems?

Answer 23: As a result of system-level testing of the assembled spacecraft, two requirements have been identified for modifying HST power management. First, thermal-vacuum testing has shown that heater power loads needed to maintain component operating temperatures were somewhat higher than expected. Second, experimental data shows that power reserves needed to implement the spacecraft's "safemode" protection in an emergency are thinner than expected.

Our response to the thermal balance problem will be operational strategies to reduce power demand, while minimizing impact on mission performance. Our response to the safemode implementation situation will likely be twofold: first, to modify some hardware and software to shorten the safemode execution time, and second, to modify commanding procedures to improve recovery from safemode conditions. These measures are under study.

We believe that these changes can easily be made in time to be tested early next year. Since final plans for modifications have not been made, we do not yet know the exact cost impact. The main costs foreseen are for the hardware and software changes to the safemode system. These will be on the order of a few million dollars, which will be accommodated by program reserves.

Looking to the future, power system performance and reliability will be enhanced by two initiatives, one already in our development plan and one newly started. Our baseline plan has always included development of a second generation solar array by the European Space Agency. This array will substantially increase HST power margins. It will be available for installation in orbit during maintenance missions. Another initiative will explore the option of providing new generation nickel-hydrogen batteries as alternatives to the present nickel-cadmium batteries. The new batteries have the potential for longer lifetimes and greater energy reserves. Depending upon the success of this initiative, the new batteries could be available at launch, or could be installed on future maintenance missions. If the nickel-hydrogen battery effort is carried to completion, the costs will be about six million dollars which will be accommodated by program reserves.

Question 24: According to your testimony, NASA is using the extra time afforded by the Shuttle hiatus to make certain modifications that will enhance the scientific return of the Space Telescope.

What is the nature of these enhancements, and what are the associated costs?

Answer 24: As indicated in our submission, we will take advantage of the delay in launch of HST to move ahead on the implementation of some of the HST ground system enhancements planned originally for post-launch implementation. For example, we will go ahead with the planned provision of full capability for tracking moving targets, including transient planetary features. This capability will support planetary science investigations. It was planned originally to provide this capability after launch. We will also go ahead with plans to install a command precedence checker, to be implemented at the ST Science Institute within the Science Planning and Scheduling System. This capability will improve ground system efficiency by eliminating potential interactions between the Science Instruments and other spacecraft systems early in the planning process. This will permit us to conserve communications time and spacecraft computer memory by removing the need to up-link and store commands to reset each science instrument to a standard start-up date.

A Data Management Facility, comprising disk data storage equipment, will be put in place at the Goddard SFC mission operations center prior to launch. This facility, planned originally for installation after launch, will relieve potential capacity overload in the early post-launch period.

The stretched schedule will be used by the operational teams to carry out more thorough testing, training and procedure refinement before launch, ultimately improving the scientific efficiency and safety of the observatory in the early stages of operation.

Since these enhancements comprise implementation of features that were already planned, and on roughly the planned schedule, we do not expect added costs to be associated with them.

Space Science and Space Station

Question 25: Specifically, what space science and applications activities are planned for the space station once it attains a "man-tended" capability, and what space science and applications activities are planned for the space station once it attains a "permanently-manned" capability?

Answer 25: Office of Space Science and Applications (OSSA) activities presently planned for the space station complex, up to the time it attains "man-tended" capability could include the following candidate experiments:

1) Attached Payloads
   * a) Plasma Environmental Monitoring System.
   * b) High Resolution Solar Observatory.
   * c) Laser Communications Engineering Test.

2) Pressurized Volume Payloads
   a) Crystal Growth Facility
   b) Combustion Science Facility
   c) Solidification Facility
   d) Bioprocessing Facility

During the time the station has "man-tended" capability, additional possible candidate payloads are as follows:

1) Additional Attached Payloads
   None

2) Pressurized Volume Payloads
   a) Fluid Dynamics Facility
   b) Containerless Processing Facility
   c) Cardiovascular Experiment
   d) Vestibular Experiment
   e) Metabolic Experiment
   f) Radiation Experiment
   g) Gravitational Biology
   * h) Gas/Grain Simulation Facility
   * i) 1.8 m Centrifuge Facility

OSSA candidate payloads presently planned after "permanently-manned" capability is achieved could include:

1) Attached Payloads
   a) STO-Solar Instrument Group
   b) TO-Plasma Instrument Group
   * c) Cosmic Dust Collection Experiment
   d) Cosmic Ray Nuclei Exp.
   e) STO-Tether Instrument Group

2) Pressurized Volume Payloads
   a) HST Servicing Instruments
   * b) 4 m Centrifuge
   * c) Life Sciences Research Facility

   In addition to the above, facilities servicing for microgravity and life science experiments will be provided. This may include modification or updating of payloads.

3) Platforms
   After the station is permanently manned, OSSA is planning for launch of space station derived polar (EOS) and co-orbiting (AXAF, SIRTF) platforms.

*** These projects are not included in the President's 1988 Budget.**

Question 26: Now that the Air Force has decided to place the Shuttle launch complex at Vandenberg Air Force Base on "minimum caretaker status" until at least 1992, it would seem that one should, at a minimum, begin planning for the possibility that this West Coast Shuttle capability may never be available.

How would the absence of this capability affect the planning for the Space Station polar platforms, which as previously planned, would require manned servicing from the Shuttle and, consequently, a West Coast Shuttle launch?

What other Space Science & Applications programs would be affected by the absence of a West Coast Shuttle capability?

Answer 26: In case there is no shuttle launch capability from the Western Test Range (WTR) each polar platform together with its payload will use an ELV single launch to its operational (800-900 km) near polar (98°) orbit.

At present we are planning for two possible approaches.

1) Continue to use satellites rather than large integrated platforms. In this case, no servicing or repair would be planned.

2) Use the planned space station derived platform concept. In this case an ELV in an automatic docking mode and a platform based telerobot will perform the necessary servicing activity. Instruments or modules, to be replaced would be discarded in orbit.

Question 27: How and to what extent will limited future access to Spacelab and other Shuttle capabilities affect our ability to productively use the space station once it is deployed?

Answer 27: The limited access to Spacelab/Shuttle flights will affect both the OSSA life science and microgravity science programs.

The Spacelab is essential for life sciences in several operational and space medicine areas, motion sickness, cardiovascular, radiation and plant physiology in relation to the development of a bioregenerative life support system. It is essential to establish procedures and requirements in environmental control and overall habitability transferable to the space station activities.

A similar situation holds for the microgravity science program. Experiments in fluid dynamics, containerless processing, combustion science and solidifications are important tasks originally scheduled for the Spacelab flights.

From a scientific standpoint, the Spacelab would serve as a test bed, needing manned interaction, for experiments in broad areas of life and material sciences and important for the transition into the long term utilization of the space station. In summary, limited future access could significantly curtail the near term productivity of the space station, as a low-gravity laboratory, because planned Shuttle precursor experiments as mentioned will have to be accomplished at a later date on the space station.

Scatterometer

Question 28: With the Navy's decision to cancel its Remote Ocean Sensing Survey (N-ROSS) satellite, you are, as your statement indicates, exploring possibilities with the Air Force of launching your Scatterometer on one of their satellites.

Depending on the launch approach you adopt, to what extent will the synergism that you had anticipated with the Scatterometer and TOPEX be compromised?

What Scatterometer capabilities will be compromised by virtue of it no longer being launched on N-ROSS?

Answer 28: The requirement for synergy due to time overlap between Scatterometer and TOPEX has previously been stated as 18 months, or a complete annual oceanic signature plus a repeat of a major season as a validation check. Prior to the unfortunate cancellation of N-ROSS, the respective launch schedules for N-ROSS (9/90) and TOPEX (12/91), coupled with their planned mission duration of 3 years each, would have yielded 21 months of overlap, thus satisfying the requirement.

In pursuing the possibilities for flight of the Scatterometer on an Air force satellite, the requirement for achieving 18 months of overlap between the Scatterometer and TOPEX has guided the selection of specific options to be explored. More specifically one of the two options currently being explored could launch as early as, but no earlier than, 12/90, while the other is planned for launch in 12/92. Since these options bracket the TOPEX launch plans by plus and minus one year, overlap of about 24 months would likely result from either option, thus meeting the requirement of 18 months.

While the feasibility studies of the 2 Air Force options are not yet complete, it appears at this time that no Scatterometer capabilities would be significantly compromised by virtue of it no longer being launched on N-ROSS. This, of course, assumes that one or the other of the two Air Force options is ultimately agreed on.

Part of the reason for this, is that the technical and interface requirements that were developed in the context of N-ROSS, are also being used for the two Air Force option studies. In fact, it appears highly probable that either of the Air Force options will look so much like N-ROSS, when viewed strictly from a Scatterometer perspective, as to be transparent.

Question 29: How does the cancellation of the N-ROSS program affect total programmatic costs for the Scatterometer?

Answer 29: Given that the various option studies for flight of the Scatterometer on an Air Force satellite are not yet complete, and thus a decision as to which option to implement, has not yet been made, it is too early to quantify potential cost impacts. Some observations of a qualitative nature can be made, however:

1) given that the N-ROSS developed technical and interface requirements are being assumed for both of the Air Force options, cost increases due to design changes should be minimized,

2) it is our understanding that, given their stated need for the Scatterometer data that would have resulted from the flight of N-ROSS, the Navy plans to fund the cost of accommodating the Scatterometer on an Air Force satellite,

3) depending on which Air Force option is selected, and minimizing cost impact will certainly be a factor in the decision, it is possible that the launch date for the Scatterometer would only be a few months delayed from that planned for N-ROSS, thus greatly minimizing cost growth due to program stretch-out.

Explorer Program

Question 30: It is my understanding that in order to adapt the Cosmic Background Explorer (COBE) from a Shuttle launch to a Delta ELV launch, the spacecraft is being reduced in weight from 11,500 pounds to 4,600 pounds.

What are the costs associated with this descoping of the spacecraft, and to what extent will the capabilities and scientific return of the spacecraft be compromised due to this descoping?

Answer 30: The weight of the Cosmic Background Explorer (COBE) is being reduced from 10,500 pounds to 5,000 pounds, mostly by redesigning the spacecraft structure, eliminating the propulsion module, and using smaller batteries, a lighter electrical harness, and an alternative communications antenna system required by the new configuration. The cost associated with the change is $28.5 million--significantly less expensive than the cost of stretching out the program four or more years, waiting for the commencement of Shuttle launches from Vandenberg.

The scientific mission has not been changed. Two of the instruments, the Far Infared Absolute Spectrophotometer and the Diffuse Infrared Background Experiment, are unaffected by the changes related to the launch vehicle, and the repackaging of the third instrument, the Differential Microwave Radiometer, will have no effect on its performance. Scientifically driven mission parameters such as orbit inclination, altitude, and spacecraft spin rate are being met in the design for a Delta launch.

Question 31: I understand that prior to the Challenger accident, NASA had planned to retrieve the Solar Maximum Mission spacecraft during a Shuttle mission so that the spacecraft could be modified for use in the Extreme Ultraviolet Explorer (EUVE) mission. However, I note that a Solar Max retrieval mission is not in the October 1986 Shuttle manifest.

Does NASA plan to ever retrieve Solar Max, and, if not, what will be the ultimate fate of this spacecraft?

Could the retrieval of Solar Max serve as the first test of the orbital Maneuvering Vehicle?

Answer 31: Since the Challenger accident, enormous pressures from other payloads have prevented the Agency from manifesting an SMM recovery. SMM is currently in 262 nautical miles orbit at 28.5° inclination. As an alternative, we are reviewing the possibility of combining an Orbital Maneuvering Vehicle "proof" mission with an SMM retrieval. However, it is uncertain that this option does not violate new landing weight constraints.

Concerning SMM's fate if not retrieved, under moderate solar flux and atmospheric density conditions, SMM could reenter the atmosphere in 1992.

Question 32: If Solar Max is not retrieved, what other plans are being developed for a EUVE mission?

Also, what means of launch are being planned for the EUVE spacecraft and the Roentgen Satellite (ROSAT)?

Answer 32: The uncertainty of a Solar Maximum Mission recovery necessitated a variation in the approach of using recovered SMM hardware and still develop a reusable, cost-effective Explorer bus. In order to maintain maximum flexibility, while taking advantage of a proven spacecraft design, the Office of Space Science and Applications is proposing the construction of a new multi-use long-life spacecraft bus. This spacecraft bus, which we are calling the Explorer Platform, is based on the Multi-Mission Modular Spacecraft (MMS) previously used for the Solar Maximum Mission and Landsat mission, and will be compatible with both a Shuttle Transportation System and the expendable Delta launch vehicle. The first payload, the Extreme Ultraviolet Explorer (EUVE), is under development at the University of California at Berkeley, and will be ready for launch in FY 1991. This mission will last 18 months. Upon completion of the EUVE mission, the Shuttle will rendezvous with the Explorer Platform and replace the EUVE payload with the X-Ray Timing Experiment (XTE). The advantages to this approach include continuing to exploit the reliability of this proven spacecraft design, sharing of spares, elimination of a large category of new development costs, flexibility in terms of launch vehicle utilization, modular design allowing for in-orbit repairs and subsystem upgrading, and commonality of interfaces to instruments (thus facilitating progress in instrument design) --all of which result in major cost-reductions and cost-avoidance in future Explorer missions. Should the SMM be ultimately recovered, then it, too, will provide a source for compatible, readily available spares for the Explorer program, thus further reducing overall programmatic risks.

The government of the Federal Republic of Germany (FRG) has stated a very strong desire that the Roentgen Satellite (ROSAT) be launched in the 1989-90 time frame. This request, coupled with ROSAT's rather unique orbital inclination requirement (58 degrees, to permit direct control and data acquisition by the FRG ground station and control center) leads to ROSAT's being designated as a prime candidate for an expendable launch vehicle rather than by the STS, as orignally planned. ROSAT appears to be compatible with either an Atlas-Centaur or a Delta II (with a 10 foot diameter shroud), either of which probably could launch in the timeframe desired by the FRG.

Question 33: What funds are in the FY 1988 budget request and are anticipated for the next five years for new Explorer spacecraft?

Answer 33: The Explorer Platform will cost approximately $100M to build and integrate with the Extreme Ultraviolet Explorer experiment. The spacecraft will be ready for launch in FY 1991 on either an STS or Delta launch vehicle. However, an ELV for EUVE has not been provided in the 1988 budget. It will be capable of a 10 year mission lifetime, providing a spacecraft bus for approximately 5 Explorer missions and thereby negating the need for additional, unique spacecraft bus developments for those missions.

Spartan Program

Question 34: The Shuttle Spartan program has been an attractive program because of its relatively low-cost, quick-turnaround approach toward Shuttle science. While I recognize that now it would be difficult to attain the previous goal of 6 Spartan flights per year, I also understand that the Spartan program now has only three flights manifested on the Shuttle betwen now and 1995.

Given that Spartans are smaller Shuttle payloads, could you explain the difficulty in manifesting any more of them than are currently on the manifest?

What is being done to compensate for this reduction in Spartan activity?

Answer 34: The difficulties in manifesting Shuttle payloads basically are the result of the reduction of the number of Shuttle flights per year, the high backlog of priority flights, and the weight available for Spartans on shared flights as a result of safety considerations.

To compensate for this reduction in Spartan activity, two fundamental options are being employed. The Spartan payloads are going through a weight reduction effort, including the design of a new carrier system which would not only reduce the weight of the system by about 1/2 but would allow up to three missions to be conducted on one flight.

It is also being planned to shift some emphasis from the Spartan program back to the Sounding Rocket and Large Balloon programs and to press for early opportunities for small payloads on the Space Station. As a part of a small payloads study effort, we are looking at future opportunities using the Scout ELV as an option to some of the smaller Spartan payload instruments.

Manifesting of Secondary Payloads

Question 35: In your statement, you refer to the need to clarify the launch status of Shuttle secondary payloads.

What criteria will you use in establishing a priority for secondary payloads, and when will this priority be established?

Answer 35: Once an Agency policy for the accommodation of secondary payloads is established, OSSA secondary payloads will be prioritized. It is appropriate to await the completion of this policy so that the statement of OSSA priorities is consistent with definitions and guidelines of the policy. OSSA priorities will be established on the basis of scientific importance of the investigation to the sponsoring discipline area, relationship of the investigation to other program activities, programmatic status of the investigation including an evaluation of its projected flight readiness, along with any other relevant considerations such as international participation.

Long Duration Exposure Facility (LDEF) Retrieval

Question 36: According to the October 1986 Shuttle manifest, the Shuttle retrieval of the Long Duration Exposure Facility (LDEF) is scheduled for November 1990.

If LDEF is, in fact, retrieved in November 1990, how much useful science do you expect to get from the experiments that were attached to LDEF, and what percent degradation of the maximum scientific return would you expect?

Answer 36: The LDEF mission carried a total of 57 experiments. While the scientific return from approximately half of these experiments will indeed be significantly degraded by the increased exposure time between now and November 1990, the scientific productivity of the remainder will actually improve with exposure time. Among the latter are passive cosmic ray track detectors and cosmic dust detectors which will benefit from the prolonged exposure to accumulate a larger sample of the very rare ultra-heavy cosmic ray events and cosmic dust particles. In summary, a significant fraction of the original scientific objectives will be achievable (and in some cases enhanced) assuming a 1990 LDEF retrieval.

Question 37: I understand that the LDEF bus has been considered as the spacebus for the Heavy Nuclei Collector (HNC) Explorer mission, which, as I understand, has now been cancelled.

What is NASA's position on the HNC mission and the use of LDEF as its spacebus?

Answer 37: The HNC/LDEF-1b Mission cancellation was a direct result of the highly constrained STS Manifest situation which has arisen in the wake of the Challenger accident. It was not considered feasible to obtain two dedicated Shuttle flights in addition to the LDEF-1a retrieval to deploy and retrieve an LDEF-based HNC experiment.

Question 38: I understand that the instruments for the HNC are being completed and are to be placed in cold storage.

How could these instruments be used other than for the HNC mission?

Answer 38: The cosmic ray track detectors which were to have been deployed on the HNC Mission have indeed been placed in cold storage. The present plan is to store these detectors until an alternate flight opportunity can be identified. A prime possibility is to deploy the detectors as an attached payload on the Space Station. Alternatively, studies have been performed which indicate that a low-cost free-flyer bus could be developed which could accommodate the detectors with minimal demands upon STS resources (i.e., volume and weight). In either case, the primary objectives of the original HNC Mission would be attained.

Materials Processing in Space (MPS)

Question 39: When West Germany and Japan are making major financial commitments to their own Materials Processing in Space programs, NASA has chosen to cut its program from $48 million in FY 1987 to $46 million in the FY 1988 request. Also I understand that an internal NASA report states that unless NASA devotes more resources to its MPS program, the U.S. may become "the landlords of the space station, not the tenants." This assessment would also seem to warn that the U.S. could surrender the potential of space commercialization if we do not adequately support our own MPS program.

Can you explain the reduction in funding for the MPS program from FY 1987 to FY 1988 in light of the commitments that our foreign competitors are making in this arena?

Answer 39: The numbers shown reflect add-ons of $7.5 million in FY 1987 and $5 million in FY 1988, specifically for development of second generation equipment for Space Station. Consistent with Congressional direction, we have prepared a Space Station Microgravity Activities Plan, which has been forwarded to Congress. Appropriate adjustments in the FY 1988 funding requirements will be considered in the development of the FY 1988 operating plan.

Question 40a: Can you compare the progress of NASA's MPS program with that of our foreign competitors?

Answer 40a: NASA's MPS program has progressed significantly in the area of theory and fundamental understanding. The linking of theoretical bases with experiment protocol design has resulted in a better understanding of flight data. Results of European experiments to date, particularly those from Spacelab 1, have not had the depth of ground-based and theoretical work underpinning the data, therefore, their results have not been as well understood.

The Europeans, however, and West Germany in particular, have flown a significantly larger number of samples, primarily on the Spacelab 1 mission on the D-1 mission, and therefore have more flight experience.

Question 40b: What institutional or technological advantages do our foreign competitors have in this area of research and applications?

Answer 40b: The foreign programs in microgravity research were established more recently than the U.S. program. Until the mid-1980's the U.S. program relied heavily on the modification/refurbishment of sounding rocket or sounding rocket-derived hardware to fly on the STS, primarily because of limited budget. The Europeans and Japanese have built their experiment hardware using more up-to-date technology, and therefore have had a better success rate in flight. Institutionally, the foreign programs, due to differences in government structure, regulation, and culture, have formed closer alliances between industry, academia, and government in the conduct of microgravity research.

Question 41: It is my understanding that one of the problems that NASA's MPS program is encountering is that of equipment that becomes obsolete almost before it can be reused.

What is NASA doing to remedy this problem?

Answer 41: In the late 1970's and early 1980's, the NASA MPS program relied almost solely on refurbished and modified sounding rocket hardware for its flight experiments on the STS. This philosophy primarily was based on the restricted funding for new hardware development, and on the pre-accident STS flight opportunities for MPS payloads.

The Microgravity Science and Applications Program has recently completed a review of all flight apparatus in the inventory, and has made the decision to "shelve" a number of pieces of equipment. This process has enabled us to free up funds in the flight program, which we will use to build up-to-date, more reliable equipment. This approach will enable us to take maximum advantage of flight opportunities once STS flights resume.

Vitality Package

Question 42: In your written statement, you refer to the "Vitality Package" of resources which will provide an infusion of research funds to support university research and to promote space sciences to graudate students as a viable research option during the hiatus of flight opportunities.

Could you be more specific about the magnitude of this funding and to which particular programs it will apply?

Is this "Vitality Package' sufficient to compensate for the opportunities that have been lost in the hiatus of flight opportunities?

Answer 42: Details about the proposed use and distribution of "Vitality Package" funding are as follows:

The current hiatus in flight opportunities represents a severe setback to the Space Science and Applications program and to the research community. Increased activities in data analysis or suborbital programs cannot make up for the fact that the Hubble Space Telescope, Galileo, Ulysses, and other important flight missions were not launched in 1986 and that we are looking ahead to delays of from one to five years in the launch of both free flyers and major Spacelab payloads. There is no way to adequately compensate for the lengthy delays of such major programs. The "Vitality Package" represents a modest attempt to provide some opportunities for new research and to help sustain viable research groups, particularly at universities, during this very difficult period.

March 1987

Vitality Package

The purpose of the NASA Office of Space Science and Applications (OSSA) "Vitality Package" is to provide additional funds to the research community, particularly universities, to help researchers maintain active research programs during the present major hiatus of flight opportunities. To be effective in dealing with the current situation, such an infusion of funds must be directed to activities which can provide immediate research opportunities and yet which do not lead to a major, long-term obligation which OSSA may not be able to sustain once normal payload development and flight opportunities resume. The vitality program focusses on the two major areas which are most likely to produce short-term results: 1) continuation of basic research, analysis of data from previous flight missions, technology development in preparation for future flight missions, and continued operation and data retrieval from currently operating spacecraft; and 2) increased activity in the suborbital program as a means of providing near-term flight opportunities, allowing continuity in research for several science disciplines which can effectively use aircraft, balloons, and sounding rockets.

The Research and Data Analysis part of this enhancement will be used to support a variety of activities. The planetary exploration program has been particularly hard hit by the Challenger accident and subsequent the decision to cancel the flight of the Centaur upper stage on the Shuttle. There is a substantial backlog of planetary spacecraft awaiting flight opportunities aboard the Space Shuttle or on expendable launch vehicles (ELV's) if they can be obtained. There is great concern in the planetary community concerning prospects for the future. The planetary portion of the vitality package will focus on advanced technology development (ATD) for the Mariner II class of future spacecraft which are a major thrust of the long-term program strategy defined by the Solar System Exploration Committee. Near-term focus is on planning and mission development activities in support of the Comet Rendezvous Asteroid Flyby (CRAF) mission now under consideration as a major new start.

Archival results from previous flight missions constitute a major resource which can be mined to obtain important new scientific results. For example, data from the previously flown astrophysics missions such as the High Energy Astrophysical Observatories (HEAO), the International Ultraviolet Explorer (IUE) and the Infrared Astronomical Satellite (IRAS) are available and there is much interest in combining data from the various missions. More than 200 letters of intent were received in response to the recently issued Space Science and Applications Notice for Astrophysical Multispectral Data Analysis. Spacelab-2 data analysis will also provide continued research opportunities for astrophysics as well as the space plasma physics community. Within the Earth science community, loss of Shuttle flights means an increased need for continued operation and expanded data analysis and Guest Investigator programs for satellites such as Nimbus, the Solar Mesospheric Explorer (SME), the Dynamics Explorer (DE), the International Cometary Explorer (ICE), and others. The research areas of materials science and life science which are critically dependent on Shuttle flights for access to space will use vitality package funds for work on enabling technology development and supporting research in preparation for future flight activities. New approaches to carrying out flight experiments such as using augmented Discover capsules for doing experiments in space medicine and biology are also being investigated.

The suborbital program enhancements will provide extra support for the ongoing aircraft, balloon, and rocket programs. By a variety of approaches (e.g., increasing the C-141 hours available, by converting smaller balloon payloads to larger flight facility class payloads able to accommodate guest investigators, and by increasing sounding rocket availability) new flight opportunities can be made quickly available to the research community allowing continued data gathering to help keep research groups active and provide ways of obtaining new results. Accelerated development of instrumentation for flight on facilities such a the DC-8 will permit geological studies using synthetic aperture radar (SAR), flight of ozone and atmospheric or oceanic species monitors, as well as biospheric experiments over the Amazon, malaria research, and coordinated interdisciplinary biogeochemical studies. Expanded availability and use of drop towers will allow new materials processing research. Sounding rocket opportunities will provide for research in space plasma physics as well as a variety of astrophysics experiments in high energy and solar physics.

In summary, this Vitality Package represents a modest infusion of funds intended to help support a broad research community for a period of 3-4 years until Shuttle flights resume. Such activities should be particularly important for allowing graduate students to carry out research programs in the near term and for keeping university research groups viable. As Shuttle and ELV launch opportunities are restored, the extent to which the basic research and analysis and suborbital programs need extra funds will decline in these research activities can then return to their normal funding level.

Global Geospace Science (GGS) Program

Question 43: The one new-start in the Space Science and Applications budget is the Global Geospace Science (GGS) program, a cooperative endeavor with Japan and ESA.

What is the total projected programmatic funding to be provided each by NASA, Japan, and ESA?

Answer 43: The total projected programmatic funding to be provided each by NASA, The Japanese Institute of Space and Astronautical Science (ISAS), and ESA, excluding launch costs, is estimated in RY ($M) as follows:

NASA	--	660	(Wind & Polar Plus Investigations on Geotail, Cluster, SOHO, and CRRES)
DOD	--	150	(Combined Release and Radiation Effects Satellite (CRRES))
ISAS	--	145	(Geotail)
ESA	--	420	(Cluster and Solar and Heliospheric Observatory (SOHO))
EUROPE	--	225	(Investigations/ESA Member Nations)

Total -- $1,600 million

NASA launch costs are estimated to be about $90 million for upper stages and $120 million for STS additive costs in RY million dollars. ESA will have effectively no direct launch costs because they are utilizing the experimental Ariane V Flight.

These estimates comprise the total support for the International Solar Terrestrial Physics Program (ISTP) made up of the NASA FY 1988 GGS Program and the FY 1987 Collaborative Solar Terrestrial Research Program (COSTR).

Land Remote Sensing R&D

Question 44: The February 16 issue of Aviation Week and Space Technology reports that Japan is planning to launch this week its first remote sensing spacecraft, and that a backup spacecraft is set for launch in 1990. When one considers this development and the growth of the French Spot remote sensing satellite system, in light of the uncertainties of our own Landsat remote sensing system, it would appear that we are on the verge of surrendering to our foreign competitors in the arena of land remote sensing.

How and to what extent is NASA's remote sensng R&D responsive to this growing international challenge in land remote sensing?

What does the future hold for U.S. land remote sensing capabilities vis-a-vis those of our foreign competitors?

Answer 44: NASA's Earth Science and Applications Program has undergone an in-depth assessment over the past several years to examine the needs for data acquired from space and the role of NASA in an overall program for the study of Earth systems processes. This examination has been accomplished by the Earth Systems Sciences Committee which has recently begun to publish its findings and recommendations.

The recommendations of this committee have established quantifiable measurement requirements and projected appropriate instrument systems to accomplish these measurements. These needs have been incorporated into the overall planning for the Earth Observing System. The range of technology development involved in the implementation of these advanced systems will push the state-of-the-art in excess of any previously developed sensors and promises to maintain the U.S. at the forefront of this technology. The NASA Spaceborne Imaging Radar (SIR) and Spaceborne Imaging Spectrometer Experiment (SISEX) are two examples of NASA's land remote sensing research and development programs.

In the case of operational users, we continue to work with NOAA on advances in meteorological and oceanographic sensors and have begun work with Eosat to define specific approaches to joint programs for the development of capabilities for the acquisition of additional data for research and commercial purposes. In August 1986, NASA and Eosat jointly produced a report defining a means to modify the Thematic Mapper instrument to acquire Thermal Infrared data and in February 1987, we jointly convened a science/operations workshop to define a modest system for the acquisition of ocean color data. In both of these activities and anticipated future endeavors we have sought to develop a "partnership" approach that capitalizes on NASA's advanced technology program and minimizes development risk to the operational contractor.

However, even with the above progress in an overall working relationship with the private sector, the continuing uncertainties in the funding of Eosat introduces questions of long-term commitment that creates a focus on near-term survivability at the expense of opportunities for future progress.

Advanced X-Ray Astrophysics Facility (AXAF)

Question 45: NASA requested $25 million for Pathfinder Advanced Technology Development (ATD) funds for the Advanced X-Ray Astrophysics Facility (AXAF), yet OMB denied this request.

How much does your FY 1988 budget request provide for AXAF activities and how are these funds to be spent? How much, if any, of this request would be used to purchase the blank glass for AXAF telescope?

Answer 45: The budget request for FY 1988 provides the Advanced X-ray Astrophysics Facility (AXAF) with a continuation of the level of funding that has been provided for the program over the past several years. $16.3 million is currently budgeted for AXAF activities in FY 1988. Of this total, $12.3 million in ATD funds are identified as follows:

Prime contractor support	$ 2.4
Science instrument definition	4.0
Optics technology development	2.4
In-house and program technical support	3.5
	$12.3

An additional $4.0 million will be used to secure the raw material for the AXAF optics. The procurement of this raw material began in FY 1987.

Question 46: When will NASA down-select from its two contractors that are competing to develop AXAF?

How much, if any, of the FY 1988 budget request will be used to support this down-select activity?

Answer 46: It is NASA's plan to initiate the process to make a selection from among the two competing prime contractors in FY 1987, leading to a selection of the contractor in FY 1988. Following selection, NASA will enter into a contract with the selected contractor for definition studies and advanced technology development. A contract for full scale design and development will of course be deferred until "new start" approval is received. As shown in the answer to question 45, $2.4 million will be used for the selected prime contractor.

Question 47: How important is the selection of the prime contractor for AXAF development to the efficient expenditure of FY 1988 AXAF funds?

Could you inform the Subcommittee about the relationship between the AXAF design and that of the Space Station, particularly the servicing elements in Work Package #3?

To what extent are the down-select of the AXAF prime contractor and the ultimate design of AXAF essential to the determination of the design for space station and the elements on Work Package #3?

Answer 47: The benefits to NASA of competitive Phase B studies have been realized from over 30 months of studies at significant technical depth. The advantages to NASA and the AXAF program of making the contractor selection, at this time, are efficient use of NASA and contractor resources and to have a single contractor work in a definitive way the NASA-wide AXAF program areas. These areas include: the consideration of use of Space Station platform modules, the Space Station servicing and operations facilities, and the interaction of AXAF with other Great Observatories. The selection will remove the burden of continuing, past the point of usefulness, the development of multiple concepts, and the maintenance of redundant dialogue with the many scientists and government contractor personnel.

The AXAF program has baselined servicing at the Space Station. The AXAF mission has been one of the major technical considerations in defining the requirements for the Space Station servicing capabilities. It is planned that the selected AXAF contractor will work detailed technical issues with the selection Space Station Work Package #3 contractor. This should significantly contribute to early compatibility of technical interfaces between these elements of NASA's programs. In addition, it is planned that the two contractors will be charged with assessing the extent to which Space Station platform modules and subsystems might be used in the AXAF program.

Question #8. NASA FY 1988 budget request for Planetary Exploration supports missions designed to survey Jupiter, Venus, and Mars by using remote sensing and other image-gathering techniques. While there is great value related to these missions, is NASA devoting enough resources to remote sensing missions and activities of Earth -- do earth remote sensing missions and activities have the appropriate priority within NASA and the Administration?

a. What earth remote sensing missions and activities are currently underway at NASA, and what future earth remote sensing missions are being considered for a new-start?

NASA's earth activities in the atmospheric, ocean, land, and biological sciences received $350 million of NASA's FY 1987 Research and Development budget, which totalled $3128 million. NASA administration is currently reviewing four major initiatives to undertake during this century: a manned flight to Mars, a sampling (unmanned) mission to Mars, the establishment of a lunar colony, and a mission to planet Earth. In part inspired by a growing realization of the effect which man can and has worked upon his environment, the goal of the mission to planet earth is to obtain a scientific understanding of the entire earth system on a global scale through an understanding of how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales. The planned payloads include some which currently have working prototypes, free-flying satellite missions already planned or begun, and new sensors. Working groups are currently meeting to identify further sensors and sensor parameters to mount on polar platforms and free-flying satellites to be launched during the mid 1990's.

CURRENT PROGRAMS

a. NASA's current earth remote sensing activities include research with and the development of both optical and microwave sensors. The NASA Spaceborne Imaging Radar (SIR) and Spaceborne Imaging Spectrometer Experiment (SISEX) are two examples. In the SIR program we have successfully demonstrated the use and utility of L-band radar (SIR-B, 1984) and are in the development and fabrication stage of SIR-C, a multipolarization, multifrequency radar experiment scheduled for launch in the early 1990's. During the interim we are developing and researching with imaging radar in the airborne quad-polarized L-band synthetic aperture radar (SAR) which is scheduled for completion and utilization during this summer, and a quad-pol C-band SAR scheduled for completion in late spring 1988. Prototypical instruments for future spaceborne imaging spectroscopy include development of and research using an airborne multichannel imaging spectrometer (the Airborne Visible and InfraRed Imaging Spectrometer) which will be flown to acquire scientific data this year.

During 1986 NASA, NOAA, NSF, and the Chemical Manufacturer Association (CMA) co-sponsored a group of scientists to use remote sensing techniques and balloon-borne instrumentation in Antarctica to study the ozone deterioration which had been observed, and in the fall of this year NASA will deploy two NASA aircraft with atmospheric sensors to monitor the peak activity period of the Antarctic ozone hole.

Instrument development began for the Upper Atmosphere Research Program (directly responsive to NASA's mandate by Congress in the 1977 Clean Air Act Amendments to develop and implement a comprehensive program of research, technology, and monitoring of atmospheric phenomena) in 1982 , and payload launch is planned for 1991. The UARS observatory will be the first satellite capable of simultaneous measurement of energy input, chemical composition, temperature and winds of the upper atmosphere, including the ozone level.

TOPEX (approved in FY 1986) will use an advanced radar altimeter and tracking system to measure the surface topograpy of the oceans, from which information ocean circulation can be determined. TOPEX is conducted as a joint mission by NASA and the French Space Agency (CNES). Scheduled for launch in late 1991, a three year mission is planned. A critical component of the funding is dedicated to maintaining adequate overlap of coverage with the flight of the first European Remote Sensing Satellite (ERS-1; planned launch in early 1990), and the large field programs of the International World Ocean Circulation Experiment (WOCE) and the Tropical Oceans Global Atmosphere (TOGA) experiment. In concert with TOPEX, the NASA Scatterometer (a radar system designed to make accurate measurements of the surface wind over the oceans) will enable an understanding of how atmospheric winds drive the circulation of the world ocean. Results of these combined efforts will pave the way for development of predictive models for Earth's climate.

PLANNED PROGRAMS

The Geopotential Research Mission is a candidate new program. If approved in the future, GRM will detect small variations in the gravitational and magnetic fields of the Earth as felt by instruments in very low orbit, permitting measurement of the Earth's magnetic and gravitational fields at levels of accuracy and precision which will make GRM a sensitive probe of the Earth's internal structure. The measurements will also enhance the scientific return of the TOPEX mission for understanding the ocean circulation system.

A second moderate potential future mission is the Tropical Rain Mapping Mission, which involves the identification of rain using radar, passive microwave,and visible/infrared imagery. Studies are underway for the implementation of this mission as either a low-inclination free flying satellite or as an attached payload on the manned core Space Station.

The primary advance mission planning activities in Earth Science and Applications focus on the Earth System Sciences Committee's recommendation for a "mission to planet Earth"; a research program which undertakes to obtain a scientific understanding of the entire earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales. The Earth Observing System (EOS) is a candidate new program that may be the means of achieving this ambitious goal. Sensors currently utilized or under development by NASA and associated agencies and the information systems designed to handle data generated from these sensors serve in planning for the sensors and information systems under design for the EOS.

Senator ROCKEFELLER. I would now ask our next panel, Dr. Lanzerotti, Dr. Nagy and Dr. Sagan, to please come forward if they are here.

Gentlemen, I welcome you. Dr. Lanzerotti, we have just received I guess what must be a very recent publication of the last few days, *The Crisis in Space and Earth Science, Time for a New Commitment.* It was released in November of 1986.

We are delighted that you are here. I know that each of you gentlemen have statements that you would like to make.

I apologize to you, Dr. Sagan, for not returning a phone call that you made to me earlier.

I have no particular order except as you may feel free to speak. I would appreciate your keeping your comments relatively short, within the five to seven-minute range. What you have to say is important, so I will look forward to it, whoever wishes to begin.

STATEMENTS OF DR. LOUIS J. LANZEROTTI, CHAIRMAN, NASA SPACE AND EARTH SCIENCE ADVISORY COMMITTEE, AT&T BELL LABORATORIES; DR. ANDREW NAGY, SPACE SCIENCE WORKING GROUP, ASSOCIATION OF AMERICAN UNIVERSITIES; AND DR. CARL SAGAN, PRESIDENT, THE PLANETARY SOCIETY

Dr. LANZEROTTI. Why don't I begin, because you commented on our committee's report? I want to point out that the report was issued by the Space and Earth Science Advisory Committee in November, but we just received the printed version in the last few days.

Senator ROCKEFELLER. Well, that is encouraging.

Dr. LANZEROTTI. The committee of which I am presently chairman is an internal NASA committee which reports to the NASA Advisory Council. My committee represents what one would call the classical areas of the space and Earth sciences that the nation has carried out with such vigor and enthusiasm and success over the last 25 years. That is, astronomy and astrophysics, planetary exploration, the Earth sciences (looking down at the Earth as a planet) and solar and space physics (the areas related to the sun and the space between the Earth and the Sun and the space environment around the Earth).

We did the study for this report, which we call *The Crisis in Space and Earth Science,* because even prior to the *Challenger* accident the space and Earth science program had been under stress for a variety of reasons, which I want to address here in the few minutes available.

With *Challenger,* of course, the Space and Earth Science Program suffered a profound setback, and our committee feels that we must get the endeavor going again; we must recover the strength that this nation's effort once could proudly claim.

Now, my committee really is a programmatic committee trying to insure that the efforts of NASA are sufficient to carry out the scientific strategies that are formulated so carefully by the Space Science Board. The Space Science Board formulates scientific strategies and direction for the nation through its reports to the National Research Council, and the Space and Earth Science Advisory Committee then tries to see that the programmatic elements exist.

When we say that there was a problem prior to the *Challenger* accident, we mean that there were programmatic issues that were beginning to increase, putting pressure and stress on the space and earth science program, even prior to *Challenger.*

For example, the character of this program is changing. There is a definite trend toward big science. Viking may have been big science, but there is more of a trend, and in more disciplines toward big science. As such, the large facilities for big science imply long-term resource commitments which can seriously impact the start of new initiatives.

At the same time, discoveries and understandings arising from this research have given rise to new space-related opportunities. The net result is that the perceived scientific possibilities in the several research disciplines, as defined by the Space Science Board largely, exceed the available funds.

Secondly, not only have the space and earth sciences widened their scientific horizons, but a more diverse scientific community is now beginning to perceive potential frontier research problems, if access to space is available. You alluded to several of these in your questioning of the NASA officials; for example, microgravity science and life sciences in space.

Thirdly, frustratingly long program delays and stretchouts prior to *Challenger* coupled with fewer opportunities for space flight experiments, mean that the time scales of various aspects of the program are inconsistent. This is particularly true in the case of university participation. There are graphs in this report which show the extended time required for getting missions into space, even prior to *Challenger*.

The time scale demanded and needed for graduate student research projects or for young researchers to establish their careers is far shorter than many recent space research projects. The nation's budgetary processes, with changes sometimes occurring on time scales shorter than one year, can wreak havoc with a well-planned, ongoing research program.

Keeping talented researchers dedicated to NASA's program requires some assurance that their projects can be carried through to completion. The directions and support of their research cannot be highly erratic. Without talented people and the institutions to support them, there would be no space and earth science program.

Fourthly, other nations now have capabilities in space and earth science research which equal, or in some cases surpass, those of the U.S. This fact can represent either opportunities or problems for the U.S. research community and can be a source of satisfaction or frustration for both the U.S. and the foreign nation participants.

Fifth, assured access to space is no longer obvious. The time between project initiation and launch was becoming progressively longer; with the *Challenger* accident, achieving access to space has become a crisis. Without assured access to space, NASA does not have a space and earth science program.

Our report, as I noted earlier, is addressed not just to NASA but to the executive and legislative branches of government, indeed to space researchers themselves, the space science research community. And we so noted in several of our recommendations, which are both detailed and more generalized and cut across all areas.

There are two things that I would like to bring specifically to your attention, and you can read my prepared statement and our report for the specific recommendations. One, the Space and Earth Science Advisory Committee has noted the need for margins in NASA's program planning. We stated that NASA's planning must not be so success oriented that unforeseen mishaps can decimate large elements of its scientific program, whether that be *Challenger* or something less tragic.

NASA seems to be planning its programs so that there is no longer any margin for error, even in some of the science programs. The wisdom of such tight planning needs to be carefully considered.

Another recommendation I would like to draw to your attention from our report is that the scientific requirements of a particular mission must be the dominant factor in selecting the launch vehicle instruments and spacecraft to be employed.

Finally, I want to draw your attention to a broader question, on the last page of my prepared statement, and which we also address very strongly in the concluding chapter, "Time for a New Commitment," in our report. NASA is at present attempting to carry out an increasingly broad space and earth science program. This became clear in the questioning of Dr. Edelson and in his presentations.

Both the scope of this program and the current stresses to which it is subject, independent of *Challenger,* clearly raise the question of whether NASA, and that means the United States, will actually be able to support such a wide-ranging program.

SESAC suggests that there are two alternatives: one, to provide adequate resources to carry out such a comprehensive national program; or two, to reduce the scope of the scientific program to fit the available resources.

We believe, as SESAC, as representative members of the American scientific community, that it is time for a conscious decision to be made concerning which course the nation is going to follow. This decision should not happen by accident. It is a national decision and will represent an important turning point for American science and American space science.

Thank you.

Senator ROCKEFELLER. Thank you, Dr. Lanzerotti. We have a problem here. I am the only Senator, and we have a vote, and I have to go do that, so I have to recess for a moment.

Before I go, and I think you refer to it in your charts of your report, there is a very clear sense of concern between what you call the announcement of opportunity and then when something happens. I guess that is part of the point that you are trying to make.

Dr. LANZEROTTI. Yes, that is correct.

Senator ROCKEFELLER. Could you explain that just a bit for me?

Dr. LANZEROTTI. Yes. The figure on page 17 includes most of the major NASA missions initiated since around 1970, most of the major ones. Viking is not on there. That graph is reproduced as a smaller version in my prepared statement.

The squares represent the time of release of the Announcement of Opportunity. The Announcement of Opportunity is when NASA puts out an announcement to the community, to the international community I should say, that a major space flight intiative opportunity is present and invites the community to propose experiments and initiatives and theoretical work for that program.

Senator ROCKEFELLER. Representing a policy decision to go forward on the part of NASA?

Dr. LANZEROTTI. That is correct. The triangles represent the launch date. The circles are redefined programs in several cases, and the dashed lines are programs not approved at the time that this report was written.

You can see from Voyager I and II, which was a policy decision in 1972, to the time of launch, which was in 1977, to the time of the Solar Maximum Mission to Spacelab I and II (flown on the Shuttle), the time progressively increased; after the loss of the

Challenger, that time into the future is indeterminant in some sense.

That graph in Figure 6 on page 17 should also be viewed in conjunction with Figure 5 on page 15, which shows a definite decrease in the launch rate, in successful space and earth science launches by year, showing a definite decrease over the years.

So those two things combined together have conspired to cause part of the crisis that we face in the space and earth sciences, even independent of *Challenger.*

Senator ROCKEFELLER. I genuinely apologize to you very distinguished gentlemen, but I have to go vote. I will recess this for the moment and will be back very shortly.

[Brief recess.]

Senator RIEGLE [presiding]. The committee will return to order. Let me ask people to find seats if they would. I appreciate the understanding of both the witnesses and others in attendance today with the fact that we have had to be interrupted by a vote on the Senate floor as well as other meetings that some of us have had to attend at the same time we have been under way here. That is always a frustration, but it is just a fact of life at the present time that we have multiple meetings going on simultaneously.

I want to thank our first witness for his statement which has just concluded, and now before we get into questions, which we will do on a panelwide basis, Dr. Nagy, let me call on you next and say we are delighted to have you here with us today and recognize your ties to our State of Michigan and welcome your comments.

If you would, I am going to ask you as well to summarize your testimony if you would, and then we will put the full statement in the record and go to the points that you feel most strongly about sharing with us.

Dr. NAGY. Thank you very much, Mr. Chairman, and members of the committee. I appreciate the opportunity to present here the statement of the Space Science Working Group.

Maybe before I start I should say to Senator Riegle that I do appreciate the kind things that you had to say about my university and our group at Michigan. Unfortunately, I was in Washington while you were in Michigan, which is a funny coincidence, but I appreciated your comments.

We at the Space Science Working Group together with scientists throughout the space science community believe that it is essential that we retain our position of leadership in space. We call upon both the President and Congress to commit this nation to strive towards a civilian space program that is second to none, and I would like to address here a few points concerning the 1988 NASA budget which may help to put us on the path to achieving this goal.

We believe that one of our national goals in rebuilding our space program should be preeminence in space science. For many years, the United States led the world in space science, and our achievements provided a highly visible demonstration of the nation's scientific and technological abilities.

As it has been mentioned earlier, however, this lead has now been eroded, and in some areas the lead has been lost. For example, the last American planetary mission was launched in 1978 and conceived nearly a decade earlier. In the meantime, the Soviets have pursued a vigorous program of planetary exploration and right now are undertaking a mission to Mars which is significantly more ambitious than anything we have planned at this time.

I personally worked for many years to plan a U.S. mission to Comet Halley, but instead of participating in a U.S. mission to Comet Halley I was in Moscow in March of last year to be a guest of Russian scientists to get a piece of the action, instead of being at JPL or at one of the other NASA centers.

Let me now say a few things specifically about programmatic issues. The Space Science Working Group is pleased to note that there is a new start for the Global Geospace Science Program in the Fiscal Year 1988 budget request of NASA. In this program, the United States will provide two spacecraft to the international solar terrestrial program.

Indeed, GSS is a paradigm for the actions we must take to retain our leadership position in space. In 1986 we got funds to provide some instruments on spacecraft which are to be built by the Europeans and Japanese to be part of the ISTP, but only with the GGS program and the spacecraft it will provide does the United States have a leadership role in ISTP. This proposed new start for GGS is an important step towards retaining our leadership but only one of many that needs to be taken.

We believe it is essential that the following four issues be addressed in the fiscal year 1988 budget. These four issues are: assured access to space; the vitality of the university infrastructure; the development of advanced technologies; and the continuing pursuit of new science. I will try to summarize those four topics very briefly.

Regular and reliable access to space is essential to a vigorous space science program. As we heard from Dr. Edelson, even when the Shuttle resumes there will be limited ability to launch all the missions which are currently waiting to fly or are under development. So it is essential that the necessary resources be provided to NASA to develop an expendable launch vehicle capability.

There are numerous examples of space science missions that can be launched from ELVs in a more timely manner than from the Shuttle. The Mars Observer mission which now has been rescheduled for 1992 could be launched by a Titan III in 1990.

ROSAT, a West German X-ray mission, to which the United States is making significant contributions, will be finished in the late 1980s. It is not scheduled to be launched until 1993, but it could be launched by the new Delta around 1990.

Galileo and Ulysses are scheduled for Shuttle launches in 1989 and 1990. Prudence requires that a Titan IV be available for these much-delayed missions.

By the way, I should mention that if the Mars Observer, which was originally contemplated to be launched in 1990 and delayed to 1992, were rescheduled for a 1990 launch there would be financial impacts specifically, an additional $55 million would be required in 1988 funds if that were to happen.

Let me go to the second topic, the vitality of the university infrastructure. Of course, that is especially close to my own heart. The health of the university research enteprise is essential to the health of the NASA space program, to the health of U.S. science and technology and, indeed, to the vigor and competitiveness of our nation as a whole.

As such, the health of the university research and education should be a central concern to our national science policy and should be of concern to all federal research agencies, including the mission agencies. Unfortunately, over time NASA has neglected its university infrastructure when it should have been nurturing it. This was not always the case.

In the 1960s, NASA had a deliberate policy and program to insure a healthy scientific infrastructure, and that was discussed earlier when Dr. Rosendahl talked in response to Senator Rockefeller's question, so I will not belabor that much more. The specifics, however, I will come to.

In fiscal years 1987 and 1988 budgets, NASA has reprogrammed $20 to $25 million to enhance the vitality of the university-based research activities through R&A and its suborbital programs. However, at this level of funding NASA's office of Space Science and Application was only able to keep some essential components of the program from dying altogether. True vitality cannot be restored in any one year with $20 or $25 million. It is only with a sustained infusion of new money over time that true vitality can be reached.

We recommend that at least an additional $25 million in new fiscal year 1988 funds be provided to this effort for research and analysis and suborbital programs.

Funds for the analysis of data for missions that are still operating, e.g. some of the Pioneers, or missions that still have useful data to be analyzed, like some of the Explorers, should be provided. The suborbital balloon and rocket program are particularly important to the science community and especially to the university community as it provides both good science and educational opportunities at a time when there are no space missions launched.

We have to train new space scientists to insure the future of the program. Very recently, there was a survey of one of our leading space science journals that showed that the average age of authorship in that journal over the last four or five years has been increasing at a rate of ten months per year. That is really a very striking indication of how the space science community is aging. Oldtimers like me will not be around much longer, so we need to get some new, young blood into the field.

I have attached a statement, a copy of testimony given by my colleague, Gene Levy, from the University of Arizona, to the House of Representatives about a year and a half ago which addresses a lot of these points, so I will not take any of your time on that.

The third item is advanced technology. Concern exists throughout the country about the competitiveness of American technology in the international marketplace. There are several federal initiatives in this area. It should be noted that NASA's office of Space Science and Application's advanced technology development (ATD) activities also contribute to the nation's technological competitiveness.

ATD activities develop the technology and instrumentation required for new space science missions. ATD is very important to the science program because it promotes the development and use of state of the art technology for these missions. Indeed, such funds not only insure that our technology is at the forefront but also that our missions are cost effective. Through the use of ATD funds, difficult components of a mission can be developed in advance of a new start, and the likelihood of costly overruns during fabrication can be reduced.

We specifically suggest that ATD funds be provided for the Comet Rendezvous Asteroid Flyby mission and the Advanced X-Ray Facility mission and for the development of other missions and instrumentations in the fiscal year 1988 budget.

The final issue that I want to touch on is new science. Preeminence in a national space science program requires vigorous support for new and continuing scientific opportunities. The proposed 1988 budget, as I mentioned, does request a new start for the Global Geospace Science Program, and we are very happy to see that, but this is only one of many fields which provides challenging scientific opportunities, and let me just mention a few examples of other science efforts which should be undertaken as soon as possible and which could be undertaken in fiscal year 1988.

One of them is life sciences. The United States plans to establish a permanent manned presence in space; however, adequate research on long duration human space flight does not exist at this time. A vigorous life science research program aimed at overcoming the physiological and psychological barriers to long duration flights should be pursued. In fiscal year 1988, a $15 million augmentation would allow this program to maintain its current efforts and build towards our future needs.

The High Resolution Solar Observatory which is planned to be the cornerstone of future studies of the sun and is a reduced scope and cost version of the earlier planned Solar Optical Telescope is a facility class instrument, which will make high resolution measurements of the sun. It is an ideal candidate for space station instrumentation. Development of this mission should begin as soon as possible, and for $12 million in 1988 it could get a good new start.

Finally, as an example, let me talk about the Explorer program, which has been one of the most scientifically productive and cost effective programs in the history of space science and which is in serious trouble.

As a result of the *Challenger* accident, it has had to absorb more than $100 million in unanticipated costs. As a result, currently planned missions have been delayed, and new missions cannot be started. NASA received 43 new Explorer proposals from the scientific community recently. We need to select a few from these 43 and proceed with them. An additional $30 million per year should be added to the Explorer line item, and that would allow the completion of the already-planned missions and allow the start of a few exciting and new Explorer missions to be launched in 1990's.

While I mention the Explorers, I should also say that in the planetary area, the Observer program is a similar cost effective and a very laudable program for which we need support.

I have briefly outlined what the Space Science Working Group believes to be the necessary components of a vigorous and world class space science program. The decisions that will be made on the nation's space program this year will determine the future of this endeavor for decades to come. Let us move forward decisively to insure that this nation's lead in all aspects of space once so proudly held does not slip away from us.

Thank you.

Senator **Riegle**. Thank you, Dr. Nagy. I must say that when I was at the University of Michigan visiting people in the space science area that they gave me very great insight, and I felt as if I was able to really get a sense as to what the full range of activities were. I was sorry that you and I missed one another, but hopefully next time I am there we will be together, and I look forward to that.

Dr. Sagan, we are very anxious to hear from you. I know this Subcommittee, and speaking for myself, has admired your work over a long period of time, and very particularly we are interested, and I am interested, in the idea that you have put forward of a joint U.S.-Soviet manned trip to Mars as perhaps the next great challenge in terms of interplanetary effort. I am sure you will tell us about that today, and we welcome your thoughts on that and other issues related to these issues, and so we would appreciate it if you would proceed at this time.

Dr. **Sagan**. Thank you, Senator Riegle. I will try to focus on just that question. There was a time when the American space program was the proudest in the world, when the exploration of the moon and planets was recognized as of historical significance, the first exploration of all the planets from Mercury to Saturn, and now we can say to Uranus, ever made in the history of the human species. That will be remembered as long as there are history books.

There were from 1962 to 1978 a set of unmanned and manned spacecraft to the moon and planets, rangers, lunar orbiters, Surveyors, Apollos, Pioneers, Mariners, Vikings, Voyagers, which have revolutionized our understanding of the solar system. Since 1978 there has not been a single U.S. launch to the moon or to the planets after dozens in the previous 18 or so years. If we look at this year's NASA budget that you had flashed on the screen briefly by Dr. Edelson, we see that while the total NASA budget this year is up some 12 percent, the allocation of funds for planetary exploration is down by 15 percent, and it is by no means clear that NASA's plans for the future are adequate to rectify this falling back from a role of leadership in the exploration of the solar system.

The human species, as Dr. Nagy said, is doing all right in this area because other nations have filled the slack left by the United States. Chiefly consortia organized by the Soviet Union, the European Space Agency, and now just starting up, Japan, and you can see those three groups active in the exploration of Halley's Comet when the United States could not do any exploration of Halley's Comet except from spacecraft that had already been in operation for other purposes.

The argument that was made was cost, but the cost was not all that great, the cost of a significant U.S. probe to Halley's Comet was less than the cost of one B-1 bomber. The United States committed to 100 B-1 bombers. Evidently 99 would have compromised national security. If we look at the Soviet program we see not only an increasingly vigorous and ambitious and successful unmanned planetary program, but we see an increasing focus on Mars, so that next year, for example, there will be a highly ambitious mission to Mars with particular attention paid to Phobos, the innermost moon of Mars, in which the Soviets will match orbit, come very close to Phobos, and do direct examination of the surface material of Phobos in the course of many other investigations, and we have just learned that a previously planned Soviet pair of missions—they always do them in twos—to an asteroid, Vesta, that was then supposed to go on to Mars has now been made Mars intensive and moved up two years so that it will now be launched in 1992, which is, incidentally, the 75th anniversary of the Bolshevik Revolution as well as the 500th anniversary of discovery of America by Christopher Columbus. I expect it is the former rather than the latter of those anniversaries that will be celebrated by that mission.

The Soviets have invited the United States to do joint exploration of Mars. I am talking about unmanned exploration. The United States was presented with these proposals in the negotiations to renew the Space Cooperation Act, which negotiations are completed and awaiting high level signatures. The United States, for whatever reason, was unable to commit to the kind of ambitious programs the Soviets have proposed, including joint rover and return sample missions from Mars.

The only U.S. Mars mission that is in the budgetary cycle is Mars Observer, a modest although significant mission, and NASA lately has, as you heard from Dr. Adelson, has decided at least for the moment to postpone the Mars Observer mission from 1990 to 1992, so as the Soviets advance their schedule to Mars we slip ours. We may pass each other going in opposite directions.

As an indication of the interest in Mars Observer something like, and it is hard to be sure, but this is the rough number, something between 15,000 and 20,000 letters have been written to Members of Congress and to NASA by people all over the country on Mars Observer. This is an activity that was initiated by the Planetary Society that as we informed our membership that Mars Observer may be slipping, but the degree of response really surprised us. These are not just checking a box on a pretyped form. These are significantly independent letters. In fact, we have a few thousand of them in the back of the room in case anyone wants to take a look.

Now, with that as background, I would like to indicate what seems to many of us a way out of the kind of problem that NASA has, and the principal reason that NASA has this problem is because there is no coherent, articulated, readily understandable goal for NASA, nothing like the Presidential directive of 1961 by John F. Kennedy, put a man on the moon and return him safely to earth by the end of the decade. That was an extraordinary technological commitment considering the difficulty of doing it. Think of where we were in space exploration in 1961, and by 1969 to land humans on the moon and bring them back is an extremely ambitious goal, and we pulled it off, and we pulled it off for a variety of reasons.

We should not imagine that Apollo was chiefly scientific. It was chiefly political. It was an American response to the Bay of Pigs fiasco and even more to the fact that the first person to orbit the earth happened to be carrying a Soviet passport. Now, the United States won that race, as all the world knows, and that sense of competition to show we can do it in space is unnecessary these days. There is, I maintain, a set of other reasons, partly scientific, partly programmatic, but the most important ones are political, to imagine a Mars goal for the United States.

I personally am very struck by the ecumenical nature of the support for a program of unmanned Mars exploration leading up to a joint U.S.-Soviet mission some time after the turn of the century. It bridges ideological boundaries, and it bridges the differences between them and in the unmanned exploration communities it is striking how many diverse groups are in favor of this as a long-term goal. And let me just indicate a few of the justifications that have been offered. I might mention that some of them are mutually inconsistent, but I claim that that is not a serious problem.

It is justified as providing a focus and sense of purpose to a dispirited NASA and on an appropriate time scale, not so close as to be easily done and therefore not refocusing the energies of the agency, not so far in the future as to have no influence on what is happening today. It is justified as a human adventure of high order, able to excite and inspire our most promising young people. It is justified as a potential scientific bonanza because Mars is so fascinating a planet scientifically.

For example, on issues of climatic change, Mars once had a billion years ago hundreds of rivers flowing all over the planet, and today is bone dry. What happened? How did that turnabout come about? Is there something there that we ought to know about our own planet? And in the scientific bonanza, the search for present or past life on Mars, the understanding of enigmatic Martian land forms, and the possible application of information gained on Mars to understanding our own planet.

It is justified as a means through robotic precursor and support missions to Mars and elsewhere of reviving a moribund U.S. planetary program. It is justified as giving a crisp and unambiguous purpose to the U.S. space station, and we have yet to hear an unambiguous justification for the U.S. space station because a space station will be needed for in-orbit assembly of the interplanetary transfer vehicle or vehicles.

It is justified as an apperture to enhance national prestige and technological development. It is justified as a realistic and possibly unique opportunity for the United States and the Soviet Union to work together in the spotlight of world public opinion and with other nations on behalf of the human species. It is justified as a model and stimulant for mutually advantageous U.S.-Soviet cooperation down here on earth. It is justified as a means for convenient economic reconversion in the aerospace industry if and when massive reductions in strategic weapons long promised by the United States and the Soviet Union are implemented.

It is justified as a worthy continuation of the traditional application of the military virtues of organization and valor to great expeditions of discovery, and then there are a whole lot of people who justify it simply as the obvious response to a deeply felt feeling of the future calling.

A goal of the exploration of Mars of this sort is something that could capture the imagination of people in the United States and all over the world and provide a sense of a benign apperture into the 21st century.

The estimates that have been made about the technological difficulty this step suggest that it is not nearly as difficult as the step from 1961 to the landing of Armstrong and Aldren on the Sea of Tranquility on July 20th, 1969, and cost estimates are, of course, risky at so early a stage, but it seems to be not much more expensive in constant dollars than Apollo, much less expensive than Star Wars, and roughly as expensive as a major strategic weapons system. That is, put simply, it is something that we can afford.

So, for all of those reasons it is garnering interest in the last two and a half years the idea has started from very little interest to very significant interest in the scientific community in the United States and in the Soviet Union, in both Houses of Congress, and in the public mind, and I think that interest will continue to build.

Thank you.

Senator **Riegle**. Let me start right there and ask you, we now have the issue of competitiveness before us. The United States asserting itself more strongly and effectively in world competition is now a front page issue. The President spoke about it in his State of the Union message. We have a proposal, I am told, of 1,600 pages coming up here literally today—Secretary Baker indicated it would arrive today—on enhancing U.S. competitiveness. We have a trade bill that many of us in the Senate are co-sponsoring designed to do that. And there are a variety of other initiatives of that kind that are being talked about in advance because of our difficulties in that area.

Let me ask you specifically with respect to the space program if we look at the next great leap out into space certainly the space station is an intermediate goal, but thinking beyond that to something like the manned trip to Mars, what are the benefits that you see apart from what we would learn, and the excitement and the challenge and all the things that you mention?

When we think in terms of that kind of a goal as a technology driver, as a driver in terms of helping this country today start to get more traction in terms of its international competitive standing and footing, how might we relate the meaning of a serious commitment to that kind of a goal to how it works back to how things would start to change beneficially in the United States today to help us across a broad base assert ourselves more so and more constructively and productively as a nation? What do you see in that area? And then I would like to ask your colleagues to respond as well.

Dr. **Sagan**. Well, my sense on this issue, Senator Riegle, is something like this. I am in general suspicious of arguments that justify large technological programs on the grounds that they will have some benevolent spinoff in some other area. I thought the argument that we should spend $25 billion on Apollo because we might get a free stickless frying pan and a cardiac pacemaker thrown in is not a good argument. If we were interested in cardiac pacemakers we have the ability to go after a cardiac pacemaker directly without sending some people to the moon in order to do it.

Likewise I think the argument that we should support Star Wars because there will be advantages for medical X-ray technology is an example of a bankrupt argument, and when these arguments start being applied, I think I often detect people who have been unable to justify their progams for the central reason of the program. Nevertheless, it is true that if you have a long-term multidisciplinary scientific program that can capture the imagination of young people that it will have a benevolent effect on the issue of competitiveness that you raise. We are in a very dangerous position of having a nation which in some sense is built upon science and technology, a competitiveness with other nations that is built on science and technology, and yet a society in which if the truth be told very few people know anything at all about science and technology, a society in which—and it is not just science and technology. It is history and geography and even reading.

Now, if we are serious about these issues, then it seems to me there has to be a major turnaround in the respectability of these intellectual issues in terms of what is talked about in newspapers and on television talk shows and all of that in the remuneration and the perquisites of teachers in these areas, and the sort of thing that Senator Bentsen was talking about about the availability of scholarships and fellowships for youngsters interested in these areas because I think there is very little doubt that in the last ten or fifteen years there has been a wholesale migration of the most talented young people away from science and technology and into, to put it simply, areas where they can make money.

And that is fine, but it produces a group of smart people whose job it is to push paper and not a group of smart people who are devising new machines, new devices, new fundamental understandings of nature, and we are going to pay the price of this if we are not careful, so my sense is that the competitiveness issue is part of a still larger and very serious problem, but that the way to attack it fundamentally is not to support this or that large program but to attack the thing at its roots, which has to do with the respectability to science and technology and the excitement that science and technology holds for young people.

Senator **Riegle**. Dr. Nagy, do you have a thought on that?

Dr. **Nagy**. Well, Dr. Sagan said most of everything that I think I would have said. I concur really with the statement. Certainly the Apollo program helped science education, helped the education infrastructure, excited young people, brought people into the field. I think the Apollo program helped our international standing. Any country which can put a man on the moon can probably make good radios or good cars also. So there are probably some indirect fallouts.

But I agree with Dr. Sagan that we should be careful not to sell these large missions on the basis that it is going to have some direct fallout in terms of better frying pans or whatever. Certainly there will be a great deal of indirect benefit.

Senator **Riegle**. Dr. Lanzerotti.

Dr. **Lanzerotti**. I am not sure what question you want me to answer. I think it has to do with the fallout from a possible big mission, and I really do not think I am competent to answer that at this point because I have not thought about that very carefully. What I would like to comment, though——

Senator **Riegle**. If I may, let me try to sharpen it for you, because I do not mean to pose the question just that way. I am not really just talking about the far-end fallout of a big mission. I am talking about everything that starts to change once you put a goal structure in place and you start building toward that future goal. If this is a 20-year process to do this, the minute you start, you begin to generate effects. I am wondering if those effects, if we take on a goal of this scale, start to accrue to our net benefit as a nation as we are going long before anybody presumably ever sets foot on Mars.

My inclination is to think that it probably does, partly because we have had this out migration of technology and we seem to be limping in the science and research area, not just space related but on a broader scale, in our country these days. I see other nations really moving ahead. We see it with the Russians in space. Now there are lots of other competitors as well. It just seems to me that maybe there is a lot to be said in terms of a focus on science activity and advanced technology work that comes from some kind of a new goal structure that at the moment I think is largely missing, and yet we have had such a structure in the past in other forms. That is really the question I am trying to pose.

Dr. **Lanzerotti**. I would say that the issue is not the near term. The United States and the U.S. scientists have well defined the science program that they feel this nation should carry out, and the resources and the wherewithal are not there at this point. They are not there at this point as our report makes adequately clear, and I really think it harkens back to the final point that I made here, the broader question of where we are going in the nation in terms of space science. Simply substituting a major 20-year goal for the science that is presently well defined and well thought out is inappropriate for the nation, and I think Dr. Sagan indicated as much in his statement where he said that it does not require refocus today. I think we are making a big mistake if we immediately consider a big program as a savior to all of the problems which exist in our national space and earth science program today. It will not do that.

And the Space Science Board has defined very well the systematic exploration of the Earth, the solar system, and the universe over the reasonably near term, for the next ten years or so, and if the nation is going to define a larger term, longer term objective, which may include a man landing on Mars, or a lunar base, or both, then there are going to have to be a much larger set of resources allocated to that so that the other programs can be imbedded in that.

We cannot—I feel that we cannot allow a larger science program or larger goal to redefine the science for us any more than we can allow the space station to define the science that we want to carry out.

Senator **Riegle**. I am going to ask one more question before turning to Senator Pressler, and that is this. We have—some people in the government have already made that decision, to sort of take a giant step in spending and resource focus and so forth, and it is called SDI. And it is a space program, if you will, and it has an on-planet aspect, but basically it is an operation that goes out into space, and it is a big ticket item.

A lot of invention has to take place even to understand the feasibility of it. But the Administration has certainly not been reluctant to plunge ahead both with the spending and the commitments of effort and so forth.

So in a sense, we have one body of opinion that sees a goal out there and is moving pretty aggressively toward it or would like to, and the question off that that I would like to pose to each of you before turning to my colleagues is this. I have been struck by the size and the growth of the space budget in the Defense Department, because it is very substantial.

I hear you talking about squeezing out an extra $12 million for this or an extra $25 million for this or to have maybe 99 B-1 bombers rather than 100 so that we might undertake a major interplanetary effort or what have you. Meanwhile, I see a burgeoning space budget in the Defense Department, much of it very little understood.

It is now roughly twice the size of the NASA budget, which seems to be, despite this year's increase, increasingly crippled in certain areas. Certainly space science is one area that seems to be having a very hard time getting funded with any degree of sufficiency.

And as you watch this trend, I would like to ask the three of you—as you watch this trend—now, we have two major space programs going. We have the Defense Department space program going, that is in the range of a $16 billion a year exercise, and we also have the NASA program going.

It would seem to me that as one grows larger and the other seems to get more anemic, that there is a relationship between these two things, and in effect the growth in the defense space program is beginning to have a very severe effect on the NASA operation.

That is the way it looks to me. I do not bring the professional know-how that each of the three of you do to this in terms of having devoted your life to it, but are we seeing that happen? I mean, are we not in effect seeing an enormous commitment of resources for activities off the face of the planet that are really being made, but taking us down quite a different road?

I do not know who would like to respond first, but let us just go right down the table.

Dr. Nagy. Well, let me try to respond. There is certainly some relation or interaction between those two from the point of view of, let us say, manpower. A growing DOD space program certainly needs manpower, and it is perceived as a growing program. So people are likely, and some very talented people, are potentially and probably gravitating towards that area.

I do not have any direct knowledge of it, but that is the way I would see it.

The scientific interaction between the two is rather minimal.

The third part that I perceived your question to be is that, if one grows, the other one has to suffer or decrease, and that is a question that I cannot answer. It is a budgetary question which you here on the Hill or OMB need to answer, but not us outsiders—last week in Science Magazine there was some chart that struck me, of how the R&D in the nation has been changing over the last decade.

While R&D is growing very rapidly, most or all of that growth is in the defense area, and the civilian R&D is suffering. So there is clearly some connection between the two.

Senator RIEGLE. Who would like to go next?

Dr. LANZAROTTI. I think that certainly there is a finite pool of talent in the United States and, as Dr. Nagy indicated, I think there has to be a tradeoff in the talent pool between the emphasis that this nation places on its defense, which is certainly a rightful direction for us to go, and its civilian research and technology, which is also a rightful direction to go.

And that decision in terms of the manpower and resources is one that is made by our elected representatives in consultation with the citizens, which you are doing here.

I would like to state that my employer is a laboratory which has long encouraged undirected, largely undirected, research, with only a long-term vision of where they might want to arrive. And I feel that at times in the nation we have tended to emphasize more the short term.

Sometimes in business the short term is driven by Wall Street. Sometimes in defense it is driven by defense concerns. But some of the research that we can do in space without any central goal in mind, whether it be in the large case of the manned Mars mission or just exploring the Earth and the space between the Earth and the Sun, can give us new insights that are applicable to defense concerns and technological concerns.

It is hard to put your finger directly on that, but certainly the environment I come from encourages that viewpoint. And I think when one answers a question or addresses a question such as you raised, I think that has to be kept in mind.

Perhaps in some instances we are attempting to overemphasize specific applications or directions of some DOD concerns in studying space, and we might get there just as well with a more concentrated civilian, more undirected investigation.

Senator RIEGLE. Dr. Sagan.

Dr. SAGAN. I agree very much with what Doctors Nagy and Lanzerotti have said. When you institute a space and technology program of the magnitude and duration of SDI, you of course are deflecting both intellectual and fiscal resources away from something else to this new program. And in this case, because the scale of SDI is so large, what we are saying is that we know the best place for the American scientific community or a significant fraction of it to be devoting its energies.

That is the best application of the limited talent that is available, and in fact no decision of that sort has been, as far as I know, thought out or made. But the effect is exactly that. People going into this field are leaving other fields.

And is this in the best interest of the country or not? It is a very significant question, and the idea of maintaining a major base of scientists who are working on fundamental self-directed research, the possibility that that might be a more cost effective way of accomplishing some national objectives, as Dr. Lanzerotti suggests, I think is a very important issue.

Also, there is a fundamental tension between the free exchange of data which is the hallmark of scientific enterprise and the necessary classified secret nature of SDI and other military endeavors in space. And that fundamental tension means that to some extent you cannot do both of them.

For example, on the space station there is a real problem about imagining the space station doing scientific research on an international basis and everybody publishes the results and at the same time have highly classified SDI research going on at the same time, at the same place. And so of course there are tensions between the two.

And I will resist saying why I think that the SDI idea is deeply and fundamental flawed, but it has been said very well by others in this room.

Senator RIEGLE. Senator Pressler.

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. Thank you very much, Mr. Chairman.

Let me say that I had a chance to visit Cape Kennedy since our last meeting, in the continuing quest to understand these issues better.

When one explores the history of NASA, one cannot help but remain fascinated at the revelations and discoveries that NASA's Space Science and Applications programs have enabled. One does not have to be an astrophysicist or astronomer to appreciate the significance of these programs to our understanding of our planet, our Solar System, and our universe.

Such spacecraft as the Viking, the Voyager, and the Infrared Astronomical Facility, to name a few, have provided and continue to provide new and profound insights into our past, present, and future. And, were it not for NASA's Space Applications programs, our nation's highly-sophisticated and productive communications capabilities might still be on the drawing board.

But now, at least for the near-term, we are in a different era—one that requires us to be more realistic in our expectations. Yet, in spite of all of the uncertainties that now plague our science and applications programs, there is one critical aspect of our space program that has crystallized. I am speaking of our space launch capabilities, and the requirement that we diversify into some mixture of Shuttles and expendable launch vehicles.

Nowhere is the affect of a single point space system failure more evident than in our Space Science and Applications programs. Before the *Challenger* accident, NASA had planned to launch 50 science and applicants missions during the period of 1986 through 1992; now only 17 of those missions are expected to fly during that same seven-year period.

This alarming reduction in Shuttle science missions only underscores the need for NASA to determine as soon as possible its ELV needs and to present these needs to OMB and the Congress. We all appreciate the difficulty in accurately assessing these requirements, but the sooner they are formally disclosed, the sooner Congress can address the attendant budgetary issues and, hopefully, expand the means by which our scientific spacecraft and instruments have access to space.

One aspect of this slowdown in NASA's Space Science and Applications programs that I find particularly troublesome is the likely affect that this will have on NASA's ability to recruit and retain qualified scientists and engineers. Similarly, this slowdown is likely to affect adversely our university space science programs, which are the lifeblood of our nation's future space science capabilities. It is imperative that as we restore our space program, we do everything possible to maintain the health and vitality of our space science academic communities. We have no other choice.

Another issue that confronts this Subcommittee and NASA is the schedule by which our upcoming planetary missions—Galileo, Ulysses, Magellan, and Mars Observer—are launched. Certainly, the pressures associated with this issue are great and are only complicated by the complexities of each of these individual planetary missions. Today's hearing will afford the Subcommittee the opportunity to explore the different considerations that will influence the ultimate decision regarding the planetary launch schedule.

Regrettably, OMB has failed once again to include the Advanced Communications Technology Satellite Program in NASA's budget request. I, for one, find it troublesome that the Administration continues to ignore the overwhelming support that Congress has given the ACTS program over the past three years.

These are but a few of the issues that the Subcommittee and NASA must face in shaping our nation's space science and applications endeavors. Others that warrant equal attention are the need to balance international cooperation and international competitiveness, the need to ensure that secondary payloads are assigned an appropriate priority on the Shuttle manifest, and the need to focus on our longer-term space science and applications goals and programs.

In closing, Mr. Chairman, I would like to draw attention to the report of the Space and Earth Advisory, Committee of the NASA Advisory Council, entitled "The Crisis in Space and Earth Science." This report does an excellent job of highlighting the issues and problems that confront our Space Science and Applications programs. Indeed, we are fortunate to have as a witness today the Chairman of this advisory committee, Dr. Louis Lanzerotti.

Perhaps, the question raised by this report that fundamentally shapes the format of today's hearing is that of, "Just how broad a Space Science and Applications program do we want—to what extent are we willing to support these endeavors?" This report offers two alternatives to this question—alternatives that are the essence of today's hearing. "Do we provide the adequate resources to carry out a comprehensive program, or do we reduce the scope of the scientific programs to fit present and projected resources?"

I recommend that as the Subcommittee explores the issues before us today, we do so in the context of the two alternatives offered by the SEASAC report. In addition to Dr. Lanzerotti, we are also fortunate to have today Dr. Burt Edelson of NASA, Dr. Carl Sagan, and Dr. Andrew Nagy. Their input and ideas will be of great assistance as the Subcommittee continues its oversight responsibilities of our civilian space program, and, especially, of the Space Science and Applications programs.

I would like to follow up on some of the questions that my colleague has already pursued. I understand that an article in the February 16 issue of *Aviation Week and Space Technology* reports that an astrophysics module including X-ray experiments manufactured by ESA and agencies in West Germany, Holland, and Britain is to dock with the Soviet MIR space station in late March or early April.

Furthermore, this article points out that the module is to remain docked with MIR at least one year and possibly two. Assuming this report proves to be accurate, what are the implications of this development, particularly in terms of U.S. space science endeavors vis a vis those of our foreign competitors?

I will address this question to the whole panel.

Dr. Lanzerotti. I think that the Soviet Union is encouraging; and certainly over the last several years—you have seen an increasing encouragement by the Soviet Union of collaboration with our—with the United States' European colleagues, whether it be in astrophysics, as in the case of the MIR space station, or whether it be in solar terrestrial research, as in the case of the Interball and Intershock satellite experiments.

And I think that this astrophysics module which you mention is just an indication of that. In terms of that particular module for doing X-ray astronomy, the United States has had a hiatus for a number of years in our pursuit of X-ray astronomy.

We discovered that field. We opened it up with rockets, and the Uhuru satellite and Einstein. Now the Europeans, the Germans with ROSAT, which the United States is somewhat involved with as Dr. Edelson said in his testimony, and this European involvement with MIR will push our foreign competitors ahead of us in that field.

But I think there is the broader international aspect. The Soviet Union is much more actively using its space flight opportunities as a foreign policy tool. I feel personally that much of the sophisticated instrumentation flown on Soviet spacecraft comes from our European colleagues.

The Soviets provide the spacecraft, they provide the launch capabilities. But much of the sophisticated instrumentation comes from Western Europe.

Dr. Nagy. Well, let me add just a general statement and then a personal one. The U.S. pioneered, encouraged, and started European space cooperation with us—and it has been successful and growing over the years, since the early sixties. However, in recent years we have been not a very reliable partner.

We have provided very few opportunities. And on a personal basis, Dr. Sagan and I, as I mentioned earlier, were in Moscow about a year ago. And when you looked around, you saw practically more Europeans, European scientists, than Russian scientists.

The Vega mission, the mission to Halley, was heavily instrumented by European scientists who, if given an opportunity would have flown on a U.S. mission to Comet Halley.

As a matter of fact, I was a member of a number of NASA planning committees working on the U.S. mission to Comet Halley, and many of the scientists in Moscow were on those panels and initially were planning to participate in the U.S. missions.

So yes, we are missing a great opportunity both scientifically and, as Dr. Lanzerotti said, politically.

Dr. SAGAN. I think the Soviets have, for whatever reason, made a remarkable turn-around from an exceedingly closed, secretive, and not terrifically competent planetary program into something that is astonishingly wide-open and increasingly ambitious and increasingly competent.

It is true that some of the successful scientific packages on board Vega and other missions were provided by Western Europeans or in one case by an American scientific team. But I would not want to overstress that. If you take a look at the imaging radar experiments flown on their most recent Venus mission, which was totally in-house in the Soviet Union, we see an extremely sophisticated technology which will be matched by the American Magellan mission some time at the end of the decade.

Just to pick up on Dr. Nagy's personal reminiscence, let me just make my point in this way. In previous visits to EKEE, the Institute for Cosmic Research of the Soviet Academy of Sciences in Moscow, I would enter through a grim security entryway with the Soviet scientist escorting me in, grilled as to what he was doing, who was I, and lots of paper documentation needed. I could go nowhere without an escort.

This last year, January, February, March of last year, a new entrance was opened about 40 or 50 feet away from the old entrance. The old entrance was still there. The Soviet scientists still had to go through the black leatherclad security people.

But we went through a glass door and, with our little badges, we were ushered in, hang up your coat, and then walk freely everywhere in EKEE. I walked into the mainframe computer center; nobody challenged me. And for whatever reason, an astonishing change in the openness of the Soviet space program is clearly happening.

And that is part and parcel of the increasing competence and accomplishment of it. A closed system has limitations as to what it can do. An open system can do a lot more.

And that then comes back to the issue raised about the tension between classified military and open scientific endeavors in space.

Senator PRESSLER. Now, there is an obvious trend towards "big science" in which major facility-class missions consume greater and greater shares of NASA's space science and application budgets. While these big science missions have provided and will continue to provide tremendous volumes of quality data, there is concern that such missions are squeezing out the low-cost and moderate-size missions and programs that typically provide scientific returns more quickly and efficiently.

What can and should be done to maintain the appropriate balance between facility-class missions and low-cost and moderate-size missions and programs?

Dr. LANZEROTTI. That was addressed to some extent. The issue was certainly adequately highlighted in our report, as you probably have seen. I think that there are things on both the side of NASA and on the side of the scientific community that can be done.

Big missions are necessary in some areas of science today. There is no question. The Hubble Space Telescope is an important American initiative which will give unprecedented scientific advances. However, the reduced access to space and the less frequent opportunities for space flight have tended to make the scientific community more prone to push for the larger missions, because if only one mission can be started in a given year or in two years, then to be a part of a bigger mission is probably a better way to cash in their chips, so to speak, to be assured of access to space.

The scientific community can probably be urged and encouraged not to push for big missions, if they are not necessary, if there are smaller opportunities available. An increase in the Explorer program, as the Space Science Working Group has advocated, would be a good direction to go, and an increase in opportunities in suborbital and rocket flights and balloon flights would be good as well.

So there needs to be a perception that there are opportunities to get into space more frequently with smaller initiatives and that these will not be held against the science community as they also push for some of the major initiatives, such as the Hubble Space Telescope or AXAF, which are also necessary for some of those disciplines.

It is a matter of both the science community's perception and a matter of NASA's pushing them in the direction of providing smaller opportunities.

Dr. NAGY. I do not think I can add anything new or different from what Dr. Lanzerotti said. But I think it is important and so let me try to repeat it with a Hungarian accent briefly.

Science requires that there be a mix of these missions. Certain scientific needs require the Hubble Space Telescope and other science can be done on a "cheap Explorer." So there are scientific drivers which sometimes make the necessity of a large mission to be large. But what is very important, as Dr. Lanzerotti mentioned, is that if there is only one mission in your field coming down the pipeline in the next 10 or 15 years, then you have got to do everything in your power to get on that mission.

And that leads to Christmas trees. If there is a mission every two years and if you do not make on the first one, you are going to have an opportunity two years from now or four years from now. So the frequency or the lack of frequency, as well as science, often drives the growth of these missions.

Dr. SAGAN. I would just say, Senator Pressler, that there are good reasons to have both kinds. And the job of program planners and people in your position is to find the right mix.

There has been a tendency to do what has been described as the slaughter of the innocent. Of course, that is a phrase invented by those who have been injured by it. But it is a feeling that when a NASA program grows unexpectedly with big cost overruns, especially on a technological development program like the shuttle or space station, and NASA cannot make up the full value of the overrun by additions to the budget, then it simply cancels or delays those missions which have the weakest political support.

And generally speaking, those are pure science missions that are not large enough to catch the public attention. And that is a clear injustice, and the long term consequence of that is it drives scientists out of the field because they have no assurance of continued funding to do work they want.

At the same time, for reasons that we have already addressed, there are good reasons for big missions, and so the mix of the two is really needed.

Senator PRESSLER. Following that up just a bit, will each of you tell me in which disciplines of space science and applications you would consider the U.S. the most competitive compared to our foreign competitors and in which space science and applications disciplines would you say the U.S. is the least competitive?

Dr. NAGY. Can I just make one more comment to the previous question very briefly? It occurred to me that I should also mention frequency is very important from an educational point of view.

If you want to get graduate students involved in the space program, a mission which takes 10 years or 12 years from inception to launch, is not useful. You cannot if you have any conscience ask graduate students to get involved in these missions. So that is important.

Yours is a difficult question to answer, and I wish I had not jumped in first, but let me try. I think certainly in the life science area we are behind. As was mentioned earlier today, Skylab was 89 days, whereas the Russian man in space program is approaching nine months or ten months or something like that. So in general we are not doing well in life science.

I would say we are certainly losing our lead in the planetary area, as mentioned earlier.

Senator PRESSLER. This is the least competitive area you are mentioning?

Dr. NAGY. Life science is maybe the weakest. We are the undoubted leader in the planetary area, and we are losing that.

Senator PRESSLER. In which space science and applications disciplines are we the most competitive, compared to our foreign competitors?

Dr. NAGY. Maybe in the Earth science area we are the strongest. Let me choose my words a little bit differently. I think we are still very competitive, up front in the solar and space plasma physics areas and the astro physics areas. We are up front, slipping, in all of them.

Planetary, we are undoubtedly the leaders, but, as Dr. Sagan mentioned, with the ambitious programs that the Russians are planning for Mars very soon we will be lagging behind. I think that is it.

Dr. LANZEROTTI. I feel that I am only competent to address four of these areas that come under the purview of my committee: astronomy and astrophysics, earth sciences, solar and space physics, and planetary.

I think that without question the United States is still the leader in the astronomy and the astrophysics area. The Soviet Union has a number of ambitious missions which they have defined for the future, but it remains to be seen how these turn out. I think they probably will turn out well, but it remains to be seen. But at the present time, I think the United States is by far the leader and hopefully will continue as such.

In the case of earth sciences and solar and terrestrial research, it is very hard to get a handle on the level of effort and competence of the Soviet Union in those two areas. There is not very much published in the earth science area in terms of remote sensing of the Earth. There is some and there are reports and things, but to get an assessment of the competence of the analysis, techniques, and sensor technology is not always easy.

In solar-terrestrial research, the Soviet Union has always emphasized that area. That is, the studies of the immediate space environment of the Earth and the sun and the space between the sun and the Earth. They have had a large number of missions in that research area. A lot of the science that has been published has not been in the forefront.

The United States has made many of the major, if not most of the major, observational advances, but not all of the theoretical advances. It is hard to get an accurate assessment. From what is published, I would say that we are leading in terms of earth science and solar-terrestrial.

In terms of planetary, it is quite clear that our studies of the inner planets have fallen far behind the emphasis of the Soviet Union. In terms of outer planets, if Galileo had been launched, and in the future looking at a Casini mission to Saturn, then we would still be leading the field in the outer planets.

And with Voyager still going to Neptune, we will still be leading in the deep outer solar system. And we have Pioneer X and XI, as well as Voyager deep in the solar system, investigating the heliosphere at long distances. We will still be leading in the outer solar system.

Dr. **Sagan**. I agree completely with what both Doctors Lanzerotti and Nagy have said. I also think that the Soviets are ahead in the issue of human physiology in Earth orbit. The only remark I would make is that the reason the United States still has a viable planetary program with the Voyagers and Pioneers that Dr. Lanzerotti mentioned is because of decisions made in the early 1970's.

We are the beneficiaries of wise decisionmaking then. It is nothing about being clever in what we have done in the last ten years.

Senator **Pressler**. Thank you.

Senator **Riegle**. Senator Gore, you have been very patient and I am going to ask that you get the same amount of time that Senator Pressler and I have taken at this point.

OPENING STATEMENT BY SENATOR GORE

Senator **Gore**. I appreciate that. I probably will not take that amount of time, but I appreciate your courtesy, Mr. Chairman.

I am delighted to hear the testimony of these three witnesses, and if the other two will forgive me, particularly from Dr. Sagan because he and I worked together on a number of projects and it is always a pleasure to hear you, I would like to apologize to Dr. Edelson for the record for missing his presentation.

The Senate Armed Services Committee was meeting on some of the projects that have been referred to, and I had to be there.

Mr. Chairman, with the passing of the anniversary of the Challenger disaster, concerns remain, not only over the steps being taken to get the Challenger program safely back on track but also with the course which NASA is following in Space and Science Applications. We must never loose sight of the fact that these programs, involving peaceful applications of space to advance the knowledge of mankind, are the fundamental reasons for the existence of the space program.

Shuttle redesign and the building of additional ELV's not ends in themselves. These vehicles are means to an end, and the end is full development of the potential for space. Therefore, it is deeply disturbing to find a 15 percent reduction in NASA's overall R&D budget from fiscal year 1986 to the proposed budget for fiscal year 1988. Again, as we have done at previous hearings this year, I believe we must ask whether major program changes are taking place within NASA's space science programs without a conscious policy—again without an overall sense of mission.

Projects such as Galileo, Ulyses, and, certainly, the Mars observer mission are slipping, not only because of the Challenger disaster but because of the lack of funding for ELV's to reduce the backlog in NASA space science issues. An additional delay of the Mars mission from 1990 to 1992 can have a long term negative impact on our efforts to explore this planet and particularly on any possible joint endeavor with the Soviet Union. Finally, elimination of funding for ACTS (the Advanced Communications Technology Satellite program) contrary to the intent of Congress is deeply troubling.

I raise these issues, not in an effort to be overly critical of NASA. I have reviewed Dr. Edelson's prepared testimony for today, and I agree with many of his points in praise of NASA's space science programs and its achievements. As with all of NASA's programs, it involves extremely dedicated men and women. We must not ignore their accomplishments thus far. What we, as policy makers, must do is to set goals and provide resources worthy of the dedicated men and women who work for and with NASA.

And I would like to go to questions on this U.S.-Soviet Mars mission that you have championed, Dr. Sagan. Here in the Senate, we are proud of Senator Sparky Matsunaga for being a real visionary in this area as well, and I would like to explore it just briefly with you.

You have done a lot of thinking about it and you have been very persuasive in your advocacy. I support the idea. I am sold on it. I think it makes a lot of sense, for the reasons that you have outlined very succinctly in your statement to us today.

But let me inquire about a few specifics. What time frame would you set? Do you know enough to make such a recommendation at this point? Let us say we really get serious about this, the Soviets are indeed interested. What time frame would be feasible?

Dr. SAGAN. A feasible time frame, allowing for the fact that there are going to be some surprises in the technological development and so on, is the first decade of the twenty-first century. I think that the idea of doing it before 2001 is barely possible, but I think that it is unnecessarily risky.

Senator GORE. Are you talking about 2010 or 2001?

Dr. SAGAN. I think that covers some of the range of uncertainty.

Senator GORE. Okay. Now, what exactly would the goal be, to put human beings on the surface of Mars?

Dr. SAGAN. I think it is proper to think of this more as a program than as a mission. And it would be a sequential development in which there would be the kind of robotic exploration of Mars that is comparable to, let us say, the robotic exploration of the Moon that preceded Apollo, the Ranger, Surveyor, Lunar Orbiter, and on the Soviet side Lunahad, the unmanned rover missions, plus an unmanned return sample mission.

And these could be done in a cooperative way. And I think it is interesting to note that you could do this in a way that the nations are not held hostage to each other. Let me give you an example.

This works at every stage all the way up to the actual human landings on Mars. Let us consider the return sample mission, which is a very important precursor. It could go either way, but let us imagine that it is an American rover and a Soviet return sample mission.

An American rover lands, wanders over a period of months over Mars, collecting samples from various exciting places, documenting all of that. It has a big bundle of labeled samples, and then it arrives at the rendezvous place with the Soviet return sample mission.

The Soviet lander lands. The rocks and salt samples are handed over and then it returns to the Earth.

Now, let us consider the failure modes. Suppose that the American lander works just fine, it arrives at the rendezvous point, no Soviet return sample mission. It is blown up on the launch pad or it could not get there. What then we have done is a successful rover mission on Mars. We have a set of documented samples. We know where they are. They are not going to go away and we will pick them up later on.

Imagine the other way around, the rover had gotten lost in a sand dune somewhere. The Soviet return sample mission lands. Okay, it cannot get samples from all those nice places. It can dig where it landed and that is a marked sample, and it has saved some of that mission.

Senator GORE. Okay. But let me get back to the question of the specific goal. What I hear you saying, you seem to be avoiding the setting of a specific goal of—you seem not to be sold on the idea of putting human beings on the surface of Mars.

Dr. SAGAN. I am sorry if I have left that implication. The clear goal for this phase will be the first human footfall on another planet.

Senator GORE. By the first decade of the next century?

Dr. SAGAN. That is right.

Senator GORE. Okay. Now, that goal you say would be achievable with budgets comparable to the Apollo program budgets, correct?

Dr. SAGAN. Roughly speaking, in contemporary dollars of course.

Senator GORE. And that is our share, is that what you are saying?

Dr. SAGAN. That is right.

Senator GORE. Now, in contemporary dollars that would be $75 billion?

Dr. SAGAN. That is correct.

Senator GORE. Now, you would see the United States and the Soviet Union alone or with other nations as well?

Dr. SAGAN. I think with at least the Europeans and the Japanese if at all possible. I think that would be well worthwhile.

Senator GORE. All right. I will submit some other questions for the record to flesh it out a little more. But let me just reiterate my feeling of support for this. I know in a time of severe budget constraints it seems a little unrealistic.

At the same time, it is abundantly clear we need to set a clear goal, an inspiring goal, one that can serve as an organizing focus, one that can have the other intangible and tangible benefits that have been described here. And count me in as a supporter for this goal.

What precursor steps and technology advances are required before we commit to such a mission?

Dr. SAGAN. Well, first, we certainly ought to have a vigorous program of unmanned Mars exploration and application of some of that technology, not just to Mars but to some other places nearby. Certainly we would want to push the Mars rover mission to make sure—sorry, the Mars Observer mission; make sure it does not slip until 1992.

Senator GORE. I am talking about what precursor steps and technology advances would be necessary before a decision to commit. None?

Dr. SAGAN. No, I think you certainly must do rover and return sample missions from Mars.

Senator GORE. Before committing?

Dr. SAGAN. Before committing to do a manned mission.

Senator GORE. Now, at the time the 1961 goal was set a lot of people have pointed out that really we knew most everything that we needed to know. It was just a matter of filling in the blanks. I may have stated that inaccurately, but that is my impression. I have read some analyses to that effect.

Are we in the same position with regard to this mission?

Dr. SAGAN. I think we know much more about Mars today than we knew about the Moon in 1961. I think we know much more about the technology that it takes and the mission design to go to Mars now than we knew about those comparable things for the Moon in 1961.

In a certain sense, we are in much better shape now for manned Mars than we were in 1961 for manned Moon.

Senator GORE. Okay. Is my time up?

Senator RIEGLE. No, you can continue.

Senator GORE. I will try to speed it up nevertheless. Thank you.

Now, there is a risk of the political relationship suffering exactly the same disruptions that have characterized that relationship throughout this century since the Russian Revolution. Is that risk a prudent one to run?

Dr. SAGAN. I think it is. First of all, as I was trying to say before, it is possible to design these missions that neither nation is hostage to a change of heart on the part of the other or gross incompetence on the part of the other. And I gave an example of it. Those examples work all the way through.

Secondly, from my point of view, yes, of course there is some risk, but I would put it the other way around. I think that it is much more important to have the United States and the Soviet Union doing a grand joint enterprise on behalf of the human species as a way to improve things down here than to say, look, there is a certain risk, these two nations have not gotten along so well and we should not do anything collaboratively.

And by the way, one of the reasons for imagining some European and Japanese presence is to moderate between the contending superpowers in case there are problems of this sort.

Senator GORE. Doctors Nagy and Lanzerotti, would your respective organizations be likely to support a mission of this kind as a flagship mission for the space program?

Dr. LANZEROTTI. My organization, you mean the Space and Earth Science Advisory Committee?

Senator GORE. Yes.

Dr. LANZEROTTI. I earlier indicated in discussions of this flagship proposal that the science community at large—and Dr. Sagan would agree with this, I believe, and I hope I say the right words, Carl—that this flagship should not be instituted such that it detracts from the space science that has already been proposed and thought out for the next five to ten years.

American scientists are not lacking for viable directions in astronomy and astrophysics or earth science, for example. And this issue raises the broader question which is in my testimony, about how broad a space and earth science program this nation is going to carry out.

And so, for a long term goal, this may be a very viable way for the nation to go, but we need to see how we are going to get to that goal without discarding our leadership in other areas of the space and earth science program and make that an integral part of a longer term national initiative.

Senator GORE. Thank you.

Dr. Nagy.

Dr. NAGY. I cannot speak on behalf of the Space Science Working Group. But speaking for myself and what I can assume that the group would support, it goes very much like what Dr. Lanzerotti said.

Senator GORE. All right, very good.

Now, Dr. Lanzerotti, there appears to be a strong consensus in your statements, in your testimony, that NASA's space science and applications programs require expendable launch vehicles immediately. Would it be fair to assume that you shared the same consensus prior to the Challenger accident?

Dr. LANZEROTTI. Personally, yes. In terms of the space and earth science community, I would also say yes, there was an increasing stress in the community on not having ready, reliable access to space.

And the science community by and large, and myself personally, felt that the particular mission that the nation wanted to do in science was not defining the launch vehicle. Rather, the launch vehicle was tending to define some of the science that would be done.

And one of the major recommendations in our report is that the scientific requirements of a particular mission must be the dominant factor in selecting the launch vehicle, and instruments and spacecraft as well. And I feel that that would have been a major recommendation, even prior to *Challenger*.

Senator GORE. One other brief line of questions about the space station. Dr. Sagan, you said in your comments that a space station would be required as a step toward a joint Mars mission, correct?

Dr. SAGAN. Yes.

Senator GORE. Would both a Soviet and a U.S. space station be required?

Dr. SAGAN. It depends on the mission design, which is of course not yet finalized. But what a space station would be needed for is to provide the infrastructure for the construction of the interplanetary transfer vehicle, a process that would take something like a year or two and involve maybe something like 20 equivalent shuttle payloads to be brought up and the parts mated.

Senator GORE. I have explored the possibility of initiating steps toward defining the legal status of space stations along the Antarctica treaty model, with rights of visitation and non-military activities, et cetera. Is that an idea that would get any support from the three witnesses here, briefly?

Dr. SAGAN. I think it is an idea whose time has come.

Senator GORE. We always love to hear that.

Dr. LANZEROTTI. I have been involved in U.S. Antarctic research for many years, with instrumentation in the Antarctic, and I have been involved in the Scientific Committee for Antarctic Research, SCAR. And I have heard presentations on the treaty aspects of the Antarctic.

I think it is a very interesting concept and it needs to be pursued in some depth.

Dr. NAGY. I think it is very interesting and a very exciting idea, and I commend you to pursue it. If I can just add one more sentence to your previous question to Dr. Lanzerotti about the pre-Challenger, accident views of ELV's versus the shuttle.

There was a concern before. It is the freight which should determine what truck you use and not the truck that determines what freight you carry.

Senator GORE. Mr. Chairman, I want to underscore their responses to my suggestion there and visit with you and others on the subcommittee a little bit later on possible strategies for pursuing this idea, given the current difficulties and controversies over military uses of our space station and what the other participants think about that.

Given the Soviet advantage in space stations for the time being, it is, it seems to me, an idea worth pursuing vigorously. And I will, with the encouragement you all have given me, I certainly intend to do that.

Dr. NAGY. Senator Gore, I am real excited about what you are talking about here. I will be going to Japan as a member of the task force for the scientific use of the space station in a few weeks, and I think that is a very exciting idea.

Senator GORE. You are welcome to discuss the Gore plan as much as you wish.

Dr. NAGY. I certainly will.

Senator GORE. Last question. A space station would be needed for a Mars mission. Your group says, if properly planned, it should be done anyway, even in the absence of a Mars mission. You seem not to—you said earlier that absent a Mars mission, it really has not been given a good justification.

Very briefly, should we go with the space station for sure, even if we do not have a Mars mission?

Dr. SAGAN. Well, it depends on what we mean by "the space station." There are a variety of possible kinds of space stations, and at the very least the space station we go to ought to be configured so that it can be used to provide the infrastructure for a later decision to build interplanetary vehicles of this sort.

The current NASA design has not been so configured.

Senator GORE. Well, as far as we are concerned there is a "the space station." I have been inside the mockup and it has got the little labels.

Dr. SAGAN. That is right, so there you are.

Senator GORE. The VCR has already been located.

Dr. SAGAN. Just to say a little more specifically, I was on the OTA space station advisory panel and we had an interesting time with NASA. NASA would come to us and say, if we had the space station here is what we could do, and then came a list of things: scientific observations, physiology, manufacture, and so on.

And we would say: Wait a minute. Do not tell us what you would do in the space station. Tell us what NASA's goal is and we can see if the space station is optimum for that goal. And NASA resolutely refused to do that, for the simple reason that nobody in NASA knew what the goal of NASA was. And that situation persists to the present time.

If there were a coherent, easily comprehended long term goal for NASA, things like the space station would fall into place. And that's one of the reasons why the Mars goal is so attractive.

Senator GORE. Mr. Chairman, in spite of my best intentions, I have stretched the outer limits of your generosity on time. I appreciate it.

Senator RIEGLE. Senator Gore, I appreciate the questions that you bring and your serious interest in these matters. The nice thing about the subcommittee is we can be flexible in terms of those kinds of time constraints.

I want to follow up on precisely this last question. I take it that within the range of choices as to what the space station will look like, can look like, that all three of you are of the view that that is the next step that does need to be taken, presumably taken wisely and thoughtfully, but that each of you would support the notion that that has to be done and carried out as the next major goal. Is that a fair summary?

Dr. NAGY. I think you phrased your words very carefully, so I am going to try to phrase it very carefully, too. I think it is important for the United States to eventually develop a permanent presence in space. The details of how that should happen and within what time frame I think are arguable.

You know, to have a mini-space station which is first man-tended and then slowly built up to a permanent presence in space, during what time period, at what speed it should develop, I think that can be argued.

I think there is good science to be done from the space station. The space station will enable—let us not call it "the space station."

But a permanent manned presence will be enabling for certain scientific endeavors which do not exist today, specifically certain microgravity experiments, it certainly will enhance life sciences.

So I think the "space station" is a good program to work towards. But we have to be careful how we take the steps, the speed, and what we finish up with.

Dr. LANZEROTTI. It cannot be answered in a simple yes or no. Please bear with me for a minute or two. I was a member of the Space Science Board when the Board said that the space station was not necessary for the science to be carried out over the next five to ten years, and I think that is still the situation.

I am now chairman of NASA's internal committee on Space and Earth Science, and reporting to my committee has been the Task Force on the Scientific Uses of the Space Station, chaired by Professor Banks of Stanford University. They have done an outstanding job in trying to input science issues into space station development.

The space station has real potentials for some scientific areas, and in other areas it will not be as useful or necessary at all. You do not need a space station to launch Galileo or Mars Observer, for example. You may need a space station for the long-term Mars initiative.

And I think in building the space station one cannot confuse ends and means. Thoughtful preparation must be made for the utilization of the space station, and the space station can only be viable if it does not decimate certain other scientific areas which cannot use it to great benefit.

So one needs to be very careful and not have an initiative which confuses ends and means in terms of space and earth science.

Dr. SAGAN. I have a similar view. What the space station is in danger of becoming is a capability without a mission, and it may even be the wrong capability. The worst situation would be to spend 10 or 15 or more billion dollars on a space station which turns out not to be the space station we need for what our tasks will be in the early twenty-first century.

And that is why I think it is so important to have a clear set of long-term national goals before there is a significant commitment to actually build a space station.

Senator RIEGLE. Well, the reason I ask that question as a follow-on to Senator Gore's questions is that we are right up to that issue, if you will, in terms of whether we are going to make that kind of long-term commitment. The dates keep slipping.

When Dr. Fletcher was here the other day, we were now talking about a date for a space station in the mid-nineties. I assume that means 1995. Now, that is quite a long time from now.

At the same time—and I do not want to just put this in an us versus the Russians context, but nevertheless they have a functioning space station at the moment. They have had cosmonauts in space for as long as 237 consecutive days. The best we have been able to do for our country with our efforts has been 84 days.

The cosmonauts that have just gone out, they are going to stay up there for 290 days. And we do not have a space station and we do not expect to have one for essentially another eight years if we stay on even the tentative time track that we are on.

I guess, not being the professional scientist that you men are in this area, I look at that and say to myself I am very uncomfortable with it. I gather that they are learning many useful things, not only the effects of how human beings deal with time in space of these durations, but other experiments and scientific activity that they presumably are undertaking I think is probably yielding important results for them.

I feel very uneasy about the fact that we are not able to, in a sense, learn some of those same things or different things, carry out that kind of work ourselves as a nation. Moreover, we have talked about doing this on an international basis, and I am very attracted to that idea. I think that is the way we ought to try to do it, for many reasons.

And the latest indications that we are getting are that maybe those negotiations are breaking down, and that maybe we are not going to be able to achieve the cooperation on an international basis that we need to have to carry out the plan as it was originally envisioned, partly because of military activities that our nation might want to perform that would cause the other nations to back away, perhaps even decide to go in some other direction with a joint venture.

So that is a whole new element of, I think, uncertainty that has been injected here at a time that I think is a poor time for uncertainty, because we already have plenty of uncertainty in the space program and by and large there is no space policy that I can see. There really is no competent space policy-setting mechanism within the executive branch of government.

I think the SIG group has been a failure, and I have said so many times. And while we have had some very interesting ideas suggested here today as a way to start to frame a long term space strategy, we are a long way from making those decisions as a country.

And now we are finding that even something that in a sense is a near-in goal, if you will, namely the space station, is now beginning also to perhaps lose its focus or that it has a multiple focus that is not totally clear. And whether or not the allies will come forward and participate with us or not is even now not certain.

So it seems to me that one of the things we are going to have to do, whether we derive the definition of a space station from precise goals and targets and so forth or whether we say we want to go to a space station and we will work out the specifics as we go as we get into the design phase, I think we do have to make a decision as to whether or not we are going to spend the money to take that step.

And hopefully, with multiple uses, interplanetary launches later on down the line, Dr. Sagan, which you referred to, plus the scientific research activities that can be done in that kind of an environment, and so forth, the station will succeed. I do know that we cannot wait much longer in deciding that in a serious way.

I think we maybe already waited too long. I think we need to do it. Now, I am willing to have that judgment challenged by others, but it seems to me that, however we end up configuring it—and we obviously want to do it as wisely as we can—it seems to me we ought to make that decision and we ought to go ahead with it.

If there is anybody that wants to file a strong dissent to that, I would like to hear that on the record, because, you know, that is the kind of decision it seems to me we are confronting here in terms of our budget decisions and our other commitment decisions.

That does not in any way preclude the debate on the choice of longer range goals. Obviously, they have to fit together in some logical sequence.

I also would like your further thoughts on this question of the degree to which we get into the expendable launch vehicles business, separate and apart from manned launches, and whether or not we should find a new way to avoid the inherent conflict between NASA doing some of this and the Defense Department doing some of this, and all of the duplication and multiple costs that can arise from that.

It seems to me that we ought to be smart enough to figure out some way now to establish an American ELV capability that is—that combines all of our efforts and it is not a military thing or a NASA thing as such, but something that is there for both areas of the government, as well as for commercial customers.

I am astonished that the policy of our government today is to say to our commercial customers: We would like you to go to the foreign competition; why do you not go talk to the Europeans, or go talk to the Chinese, or talk to anybody you can find, and we would really like you to take your business overseas.

It just does not make any sense whatsoever. And what we ought to be doing is figuring out how, within the public sector or some public-private consortium, we ought to figure out how we get ourselves fully into the space launch business for the commercial side of the space launch activities, and that we not be second to anybody in that area, but that we step right out and do it.

That is another area that is very unclear. But I am wondering if the three of you would be of the view that says that, rather than have this fragmented sort of effort, especially when there is not enough money to go around and do all the things that everybody wants to do anyway, that we should not, at least with the expendable launch area, force a consolidation, get people out of either their defense hats or non-defense hats, and maybe we have no hats or everybody gets the same hat, and we work this thing out so that we have the capability that services all of the needs in the country.

When I talked to the scientific people at the University of Michigan who have experiments that have been waiting for years and are ready to go and want to get them up and there is no way to get them up, it seems to me that that is something we can and should respond to.

And the same with the commercial customers that come in. I do not think sending them to the Japanese is any answer. I think that is a failure of an intelligent decision on the part of this country.

What can we do in that area? What do you have to suggest to us?

Dr. SAGAN. It is not—it is worse than what you said, because there is the issue of launch of military reconnaissance satellites like the KH-12. And those satellites, especially at a time when there is a saber-rattling here and there, are, as Lyndon Johnson once said, worth their weight in gold.

It is very important that we maintain a cohesive reconnaissance capability over the whole planet. Now, of course we should maintain a fleet of non-reusable, expendable launch vehicles, and they ought to be available for military as well as civilian purposes. And the Department of Defense has not been nearly so short-sighted as NASA in this regard, so that they at least have some expendable launch vehicles.

Now, it is an important question: How did we get into this foolish situation of all of our launch eggs in one basket? Did it happen, as some people think, because the military tried to force NASA into some situation? Not at all.

The situation is the exact opposite. Because of NASA having no coherent goal, NASA officials decided during the Carter Administration that it would be very good if shuttle were the sole launch vehicle for military payloads, since there was a guaranteed need for launching military payloads. This would then provide a continuing mission for NASA.

And on cost grounds, they convinced President Carter to go in that direction, even though lots of people, including lots of military people and lots of people in the intelligence community, were saying that there is something very dangerous about this in case something goes wrong with the shuttle.

So I mention this only to indicate that the absence of a goal for NASA then means that NASA goes around trying to find its own goals, a means for its own institutional continuance, and that can work in the short term fine and in the long term disastrous. It is another example of why a long term goal is required.

On your first question, Senator, about we cannot keep postponing decisions on space station, otherwise we will never have one, I agree with that. But it is possible, for example, for Congress to say: Yes, we authorize this amount of money for a space station, but you NASA have to in turn guarantee that the space station will be optimized for the following possible goals. And it would put first on that list the manned Mars mission at some later time.

This does not take away from any of the other goals. It is just a question of short-sightedness to leave it out.

Senator RIEGLE. Dr. Nagy, you were about to respond at the same time.

Dr. NAGY. Well, in some respect I support what Dr. Sagan said. I think if you succeed in organizing a unified U.S. policy or entity for the ELV, you will have achieved something significant—the Nation will owe you a great deal of thanks.

And as you said, it makes no sense to have a NASA plan for ELV and a DOD plan for ELV and argue about who gets what and when. The United States should have an ELV plan.

Dr. LANZEROTTI. You covered, Senator Riegle, a broad range of topics, and I want to touch on two or three of them if I may. With regard to ELV's, there is no question that my committee and myself personally feel that there needs to be a national fleet.

Whether it is to be consolidated or cooperative, I do not know. As a voting citizen of this country, I feel that oftimes discussions that enter into these kinds of decisions are not always carried out with the goal in mind that we want what is best for the nation. I think it is a management decision and a situation that needs to be thought about very carefully by NASA and the DOD, with strong encouragement from the legislative branch.

But without the ELV's, we have no access to space. And without access to space, there is no space and earth science program, as I indicated earlier.

And with regard to the space station, the nation certainly needs a long-term goal. If the long-term goal of the nation, prior to a possible Mars initiative, were a permanent manned presence in space, then a space station would be more obvious, as well as the kind of space station, because one could then look at the space programs, and the application programs that might be able to be carried out therein.

Not all sciences would benefit from the space station, and we cannot kill that science which is not going to benefit from the space station, whether it be planetary or astrophysics. And that is the problem, that we are always mixing ends and means because we do not have a long term vision.

One should be asking why the Soviet Union has developed, slowly and gradually over 15 years, a manned presence in space. What is their long term goal? It is likely long term human habitation in space, and maybe on the Moon. If that is their goal, then the directions they are going are very sensible.

We do not have such a goal, we will not have such sensible directions. And at the same time, the Soviets are moving out in the science areas. Their space station is not killing off some of their solar terrestrial science, nor some of their planetary initiatives.

Finally, I would like to address, and with perhaps a slightly different twist on the ball, the issue of foreign involvement and DOD involvement in the space station. We blew it as a nation! The DOD said it had no interest in the space station, and all of a sudden in the last month—this is my personal opinion, not the committee, not my employer—what I see is that in the last month or two, all of a sudden the DOD has an interest in the space station that is broadcast in all the newspapers, on the radio, and our foreign partners get all upset.

It is absolutely stupid. Nobody can tell me that there is not some Soviet military involvement in the MIR space station or in the space initiatives that went before. But our foreign partners are still sending up an astrophysics mission to be coupled to MIR.

Now, why is that? That is because the Soviet Union did not blow it; they did not put it all over Pravda that they were doing SDI or whatever else they were doing on MIR or in their space stations. And so our foreign partners do not get upset because it is not broadcast in European newspapers.

Why do we blow it all the time? I do not know why we blow it all the time. But as a citizen, I get upset about that. Maybe we should not be doing it. It is almost irrelevant at present whether we should or should not be doing SDI or DOD on our space station. It is just how we go about making these announcements which alienate all of our foreign partners all the time, from the cancellation of Ulysses to the DOD issue on the space station to other initiatives which our foreign space science partners get upset about. I can recite further examples.

So it is almost a non-issue at present, and yet we blew it. And so now we have got everybody in NATO unhappy with us again, and the Europeans are sending up their astrophysics package on MIR, which probably does some DOD things for the Soviet Union. That is crazy.

Thank you.

Senator RIEGLE. Senator Gore, you wanted to interpose a postscript?

Senator GORE. That was a very impressive statement.

I wanted to make a very brief comment on one of your—your inclusion of commercial launch capability in your comment, and just note for the record that the Administration is guilty, in my opinion, of extremely sloppy thinking when it says that a U.S.-subsidized commercial launch capability is unwise because it crowds private launch capability out of the market.

They have never answered the obvious question, and that is why would not a Japanese, Soviet, Chinese, European subsidized launch capability suffice without U.S. government launch capability to accomplish exactly the same purpose of providing a disincentive for private investors to get into the same business?

It is asinine to assert that the removal of the United States from that enterprise would suddenly create this vacuum into which private investors are going to rush. It is stupid. They have never answered that question, and they just go right on as if the question does not exist.

So I just wanted to underscore your comment.

Senator RIEGLE. Well, we are coming to an end here today, and I appreciate your comments and your testimony and your patience with us as we had those interruptions earlier. But in trying to get a sense on space strategy and space policy for the future, which is what this subcommittee hopes to do, and as you start to unwind where we are and how we got here and all the unresolved issues, it seems that the policy-setting machinery is not working very well.

And so some of us have made the suggestion that we need a different decision structure, and so we have suggested re-instituting the National Space Council under the direction of the Vice President. It is certainly not a novel or a new idea, because we used to do it that way and it seemed to work quite well when we did.

Now we are into a different institutional format with the SIG group, and the SIG group seems, for whatever reasons, to be unable to work its way through these issues clearly and crisply and on a timely basis and with some intelligent end result.

And I do not know whether it is because there are too many of those members who were sidetracked with arms to Iran and proceeds to the contras and what have you, because you have got a lot of the same players. But in any event, there has been enough of a diffusion of focus and decisionmaking that we have not really gotten very good space policy decisions.

And now it seems to me serious people who care about the future of the United States in space, from the private sector players on through the public policy people like yourselves and many others, are coming to the conclusion that we really do not have a clear strategy for the future, we do not really have a clear notion of what we should do next, or why or how.

Now, having said that, we obviously know that the shuttle has to be fixed, and that is being done and so forth. But I am talking about the broader strategy questions that we have been touching on here today.

I think there is a general consensus among most serious people that really we are not making those decisions as a nation in any clearcut, focused fashion. And frankly, I do not know that there is much great interest in that area of decisionmaking at the upper reaches of the Administration.

I am not quite sure where the priorities lie these days. I think they lie in other issue areas and not so much in this issue area. And so this has, I think, compounded the feeling of things languishing that I think has many of us concerned.

What we are going to try to do and what we need your help to try to do is to try to isolate those basic decisions. We did pass legislation last year to reinstitute the National Space Council approach. It was vetoed.

We hope to do that again, and we hope to get it enacted this time around. People who support that, we would like some help on getting that done, not because it is anybody's particular inventive creature but because it seems to be a more sensible way to try to start to get some of these decisions made in an orderly fashion.

I would like to see us move to the question of expendable launch vehicles and get some sort of intelligent discipline around that problem. I think we need to have a much crisper goal structure, immediate goals, intermediate goals, long term goals, and they have to fit together.

If we do not do that, then I think we just keep bumping into one another. I will just say one other thing about it. I serve on the Budget Committee and Senator Gore is very much involved in the budget issues as well. We now live within the discipline of Gramm-Rudman-Hollings.

It says, among other things, that the Federal budget deficit for the coming fiscal year will be $108 billion. For the first year, the year just finished, the previous fiscal year, the Gramm-Rudman-Hollings legal limit was a $172 billion deficit.

We came in at $221 billion. Nobody writes that story because that is yesterday's news. I think it is a big, important fact, however. But as the squeeze tightens here to try to come within at least rifle shot of these Gramm-Rudman-Hollings targets, there is a real compression going on.

It is going on in every budget function. It is obviously going on in space activities. I think the defense space program is really putting a crushing pressure on the non-defense, civilian NASA type activity.

And if we do not get some policy decisions that are thoughtful and figure out how we get the most of what we really want for a shrinking amount of money that is available to do it in the overall, I think we are going to miss the mark by even more and we are going to be sitting around two or three years from now, everyone will be scratching their head and saying: How did we get so far off course? How did we manage to sort of bungle these decisions at a time when we could have made them with some precision and some care?

So I guess I am expressing the feeling, and I think of others on the subcommittee, that we want to try to bring some measure of clear decision as much as we can get to those questions, now that we have some opportunity to at least sort of be in charge of the authorization and goal-setting process here in the legislative branch.

So we will need your help on that, and I would hope that we could continue to work together along those lines, because I think that is the key to making some real progress.

I do not know if you want to add anything.

If not, I want to thank the witnesses for coming. It has been very constructive, what you have had to say to us today, and we look forward to future discussions with you.

[Whereupon, at 5:27 p.m., the subcommittee was adjourned.]

NASA AUTHORIZATIONS

THURSDAY, FEBRUARY 26, 1987

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met, pursuant to notice, at 2 p.m., in room SR-253, Russell Senate Office Building, Hon. Donald W. Riegle, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR RIEGLE

Senator RIEGLE. The subcommittee will come to order. We have a witness already at the table, and I am going to make just a few initial comments before calling on that witness. Dr. Colladay, we are delighted to have you with us today, and I am pleased to acknowledge the fact that you were born in Flint, Michigan, of all places, on July 7, 1943, and you came along about five years after I did. I do not know if it was at the same hospital in Flint, but it may have been. In any event, we are delighted to have you here, and take note of your earliest origins, if you will.

Senator WILSON. Is there a shrine at that hospital?

Senator RIEGLE. Not yet, but we are hopeful.

This is the third budget hearing of the subcommittee. Today we are going to focus on the aeronautics and space technology programs of NASA. These are programs which, while sometimes obscured from view because of the shuttle and space station programs, are nevertheless of major importance to the economic vitality of the United States, and, I think, our competitiveness and our ability to function in world markets.

The U.S. aeronautics industry is by anyone's calculation the world's leader. A walk though any airport in the free world shows that. Boeing, McDonnell Douglas, Lockheed are represented by their aircraft, and it has been that way for many years. In a year that saw the U.S. trade balance plunge to record levels with a deficit of more than $170 billion, the aeronautics industry produced a surplus for our nation of almost $12 billion, and by all appearances our industry is healthy, competitive, and able to withstand any competition that might come its way in the future, and hopefully that is not an overly optimistic view, but we need to keep it that way.

I am not sure that I believe those who make such a sweeping claim, and we are going to hear testimony today that I think will raise our level of concern. While our exports have grown modestly, imports of aeronautics products shot up 40 percent in one year.

Other nations have made national commitments to enter the aeronautics market and have backed this commitment with huge investments in research, development, and manufacturing. These nations are our traditional competitors such as France, Great Britain, or West Germany, but they are also nations with little or no aeronautics industry at this time, nations such as Japan, Brazil, and Indonesia.

NASA is the lead Federal agency in aeronautical research and development for the United States. Many of the advances that have occurred in commercial aviation, advances that have enabled our industry to capture a major share of the market, can be traced directly to NASA and the work that was done to develop new engines, new aircraft, new avionics, and the like. NASA's investment over the years has been matched by an aggressive R&D program funded by industry. Perhaps the aeronautics field is the best example of the necessary partnership between government, industry, and the research communities and universities and private centers.

I am concerned about the level of funding in this account and whether it is sufficient to meet the competition from abroad. We have aging test facilities, some that date from before World War II, and we have a no growth budget in a time when the technology advancements require incredible investments just to stay even. So this is an area that we must explore at length because we must be able to do things today that will produce results in the near term as well as keeping our eye focused on the distant future.

Two other programs are in this area that we will discuss today. They are the National Aerospace Plane, a joint DOD-NASA program, and the Space Research and Technology Program. The National Aerospace Plane is a program with tremendous promise in the long term. It represents a major advance in technology, in design, in concept, and is an endeavor that should be encouraged by the government.

On the space side we find one of the major new starts that was proposed by NASA for fiscal year 1988, and that is the Civilian Space Technology Initiative. The purpose of that program will be to do the initial work of planning and developing the spacecraft and systems that we will need to maintain a permanent and growing presence in space. It is the long-range visionary program within NASA, something that we have not had for a few years.

Research and technology have been the trademark of NASA since its beginning. They are what brought us to the prominence the program enjoys today, so in crafting the budget for NASA I want to make certain that we are doing what we need to do to maintain this capacity within NASA, and in a way that is going to match and hopefully exceed whatever competition internationally comes our way.

Before introducing Dr. Colladay, might I ask, Senator Wilson, do you have any opening comments you would like to make?

OPENING STATEMENT BY SENATOR WILSON

Senator **Wilson**. Thank you, Mr. chairman. I would only say that I think that you are giving proper emphasis to this aspect of the important work of the agency and it is tremendously important.

We in this country have chosen to pursue a different path than our trading partners. If we were engaged in a truly free market competition, air carriers that are now sponsored by heavy subsidy from our trading partners would find themselves, I think, at a real competitive disadvantage with American air carriers. That is not the situation that we confront, so I think that we have before us a particularly difficult challenge in determining not only what the proper research program is but also what the proper role, the proper involvement for government should be, and what you have described as a useful governmental and private sector partnership.

I think this partnership has been useful and can continue to be. Furthermore, I think that we need to view the aeronautical work of NASA in the context of the current market environment in which our competitive aircraft manufacturers are subsidized or in air carriers are engaged to focus on just that enjoy other such advantages. I won't say any more because I am eager to entertain the testimony of the witnesses.

Thank you, gentlemen, for being with us today.

Senator Riegle. Thank you, Senator Wilson.

I have a statement from Senator Hollings for the record.

[The statement follows:]

OPENING STATEMENT BY THE CHAIRMAN

Today, this Subcommittee will review the fiscal year 1988 NASA budget request for the NASA Office of Aeronautics and Space Technology. The Subcommittee also will explore the competitive posture of the U.S. aerospace industry.

Today's hearing is important for two reasons. One, we will discuss how government research and development activities can help U.S. industries compete in world markets of today. Two, we will discuss the importance of government advance technology development activities to future space exploration and future commercial aerospace activities.

I am pleased at the outset of this hearing to indicate my full-fledged support of the Civilian Space Technology Initiative (CSTI). I think this initiative is a step in the right direction, and I think Dr. Paine and the members of the National Commission on Space should be complimented for making the Members of this Committee well aware of the technology requirements of NASA and the civilian space program and for laying the foundation for this initiative. However, I do feel CSTI is but a small step in the right direction and that its bredth and scope will need to be increased in the future if the U.S. is to retain its leadership in space and if the U.S. is to undertake any bold new initiatives such as a lunar base, a manned Mars mission, or a liquid oxygen-hydrocarbon propulsion system for the next generation space transportation systems.

I also want to indicate my concern with the aeronautics portion of the fiscal year 1988 NASA budget request, which reflects no growth despite the fact that aerospace continues to be one of the best U.S. export markets. I would hope to discover today that the shift in priorities in the fiscal year 1988 NASA budget request for Aeronautics and Space Technology is not at the expense of the aerospace export market.

Finally, I would like to welcome Dr. Graham, the President's Science Advisor; Dr. Colladay, the Associate Administrator of NASA; and Dr. Norris Krone from the Aerospace Industries Association of America, who are here to present testimony. We appreciate your support of the Nation's aeronautics and space technology research and development activities and hope that with your help these programs can be better tailored to make America more competitive in world markets.

Senator Riegle. Dr. Colladay, it is a pleasure to have you before the subcommittee today to discuss the budget request and our competitive posture in the world markets. As you know, the whole question of U.S. competitiveness is as much as anything the driving issue today in the Congress, so we are very interested in your thoughts along that line. Also, I am sure we would be interested to hear any of your impressions of really a great success story of last year, and that is the flight of the Voyager. If you want to make any observations about that in terms of where we are and where we are going we would be grateful. In any event we would be pleased to have your summary today. We will make your full statement a part of the record.

STATEMENT OF DR. RAYMOND S. COLLADAY, ASSOCIATE ADMINISTRATOR FOR AERONAUTICS AND SPACE TECHNOLOGY, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY DR. ROSEN, DEPUTY ASSOCIATE ADMINISTRATOR

Dr. **Colladay**. Thank you, Mr. Chairman, Senator Wilson. It is a pleasure to be here, and I am proud to be from the State of Michigan, Senator Riegle, and we both know what a great State that is. I find that I appreciate it more and more since I have left, but I do get back there quite often because my family still lives in the State.

I do have a short statement that I want to just summarize a few points for emphasis, and I am pleased to submit the written statement for the record.

Senator **Riegle**. Very good. Do you want to introduce Dr. Rosen, who is with you?

Dr. **Colladay**. Yes, Dr. Rosen is my Deputy. He has been in that position for just about a year now, and he is the full deputy of Aeronautics and Space Technology, and he will be helping me with question that you might have that we can handle as a team, and I also have my Director for Space, Director for Aeronautics, and the Director of the Aerospace Plane in the room, too.

The requested budget for Aeronautics, Transatmospheric and Space research and technology for fiscal year 1988 reflects a growing commitment to R&T and a recognition of the importance of advanced aerospace technology to NASA's mission and to the U.S. economic and strategic competitiveness, which you also pointed out in your introductory statement. We have established a healthy trend, and I use that word and emphasize it, a trend that has seen a 40 percent growth over the last two years in advanced technology in the agency, and we are focusing on cutting edge technologies that will help sustain the U.S. competitive edge.

For fiscal year 1988 NASA is requesting $375 million for Aeronautics R&T, $66 million for Transatmospheric R&T, and $250 million for Space R&T. Aerospace, particularly the aeronautics sector, is one of the few bright spots in the U.S. balance of trade picture. U.S. leadership in aeronautics has not happened by accident. However, it is the result of a highly successful industry, government, and university partnership which has evolved since the founding of NACA over 70 years ago, pioneering new technology, which is the way this country has always remained competitive. But, the picture is not as rosy as the statistics would indicate. In fact, other nations now dominate the world general aviation market, account for nearly half of the world sales of rotorcraft, and Airbus is achieving growing market penetration in the large commercial transport market. Technology can make a difference, and what we do now in technology development will affect in large measure how well we compete in the 1990s.

We have laid out a strategy for dealing with aeronautical R&D on a coordinated national level. The Office of Science and Technology Policy Goals Report that was published two years ago and its sequel implementation plan which Dr. Graham will mention in his testimony later, are important documents in that national view for aeronautics. Work on all three of the report's principal goals in subsonic, supersonic, and transatmospheric flight regimes is in progress. The aeronautics budget request of $375 million allows us to move forward in several new areas and enables continued progress on some very important technical initiatives related to the R&D goals.

In wind tunnel efficiency enhancement, this budget request provides early funding to improve the productivity and quality of our most critical wind tunnels as a national resource for aeronautics. The high temperature engine materials, a new line item in the budget, represents a consolidation and expansion of ongoing fundamental materials research in ceramics, carbon-carbon composites, and metal matrix composites. This past year the Numerical Aerodynamic Simulation facility at our Ames Research Center entered service and will be dedicated officially March 9th. This advanced facility for computation fluid dynamics will formally usher in a new era for applications in aerodynamics and related fields and we already have over 190 users on remote terminals throughout the United States.

As to the subsonic goal specifically, technology that we have invested in over the past ten years, primarily in the Aircraft Energy Efficiency program, is maturing to the point where industry is now preparing to apply it to products for the early 1990s. For over a decade we invested well over $1 billion in critical fuel-conserving technology for subsonic transport aircraft and that is beginning to pay off, and it is a good example of successful transitioning of government advanced technology to U.S. industry. NASA's pioneering efforts in propellers, for example, led the way for GE and the rest of the industry in the area of high speed turboprop technology, but there is more to be done.

We are also focusing on the technology base with emphasis on aircraft automation, aviation safety, composites, and laminar flow concepts. In the high speed rotorcraft area we plan to begin flight testing in April of the new RSRA/X-Wing Aircraft.

The supersonic goal remains the great opportunity that is yet to be exploited. During this past year we embarked on major high speed transport studies with the industry to examine the market opportunities for that flight regime, to determine the necessary environmental characteristics of such a vehicle, identify the most promising aicraft concepts in cruise speeds, and define most importantly the necessary research and technology efforts that need to be initiated to lay the foundation for a thrust in that area. Also in the supersonic area we are continuing to explore technology for advanced fighter aircraft which have unprecedented maneuverability and the ability to take off in short distances and land vertically.

In transatmospheric flight we are right on track. NASA's aeronautics research related to hypersonic flight has been successfully transitioned to the National Aero-Space Plane program. This bold initiative to sustain U.S. leadership is stimulating a major expansion of research in all the technologies key to transatmospheric and hypersonic flight. We have put the joint NASA-DOD team in place to manage the program. It is making excellent progress. The five air frame and three engine manufacturers are under contract and also making excellent progress, and we have about 300 NASA scientists and engineers dedicated to these efforts, at our various centers across the country.

We are requesting $66 million for the Transatmospheric R&T element in fiscal year 1988 to be combined with $18 million from the Aeronautics and Space R&T Base for a total NASA request for this program of $84 million. That compares with the DOD request of $241 million and the budget growth for the entire program reflects the fact that in fiscal year 1988 we will be moving into large-scale engine design and fabrication for the all-important propulsion tests leading to the X-30 experimental vehicle.

Our request this year for space research and technology reflects a reevaluation of what it takes to sustain leadership in space. I am very pleased with this budget request. We are proposing the Civil Space Technology Initiative to begin the restoration of the technology base as a first step in rebuilding for the future. CSTI, as we call it in acronym form, is an integral part of our recovery plan. From an historical perspective, the U.S. civil space program began with the recognition that heavy research and technology investments had to be made to support a national commitment, but the advantage gained from those early investments has been lost.

Beginning in the 1960s our space R&T budget dropped from a 6 percent level of investment to about 2.5 percent of the total space NASA budget. Meanwhile, large foreign R&D investments across a broad range of space endeavors have been growing, not just for the direct return but also because it stimulates the overall technological advancement of these nations. We find ourselves in a situation where technology is no longer leading with options for the future but is chasing problems. The Civil Space Technology Initiative begins to turn that picture around. The space research and technology budget request of $250 million includes a $70 million augmentation as part of the CSTI effort, and it totals $773 million over five years, combined with some redirected ongoing efforts.

The program was carefully developed with the help of industry, the university community, researchers who knew what was possible, and users who know what is needed. It is focused on critical gaps in the technology base that fall within three general categories: safe and efficient access to space, earth orbiting operations, and science supporting technology, and in my prepared statement for the record there is considerable detail on each of the individual ten program elements. I will not go into the detail on those right now.

The timing is right for CSTI to contribute to the recovery of the Nation's space program. Just as important, CSTI will develop, nurture, and stimulate human resources by providing cutting edge research and technology with a clear direction and provide a magnet for new talent fostered by increased involvement from our engineering schools.

Historically, technology has been the cornerstone of our leadership in aeronautics and space, and I believe that the three elements of the advanced technology program taken together in aeronautics, space technology, and aero-space plane technology is a positive step forward.

I understand the important role that my office plays in developing and transferring that technology to stay competitive, to make sure that we reach far enough, but that there is something real to grab hold of, and if someone is going to be pulling rabbits out of the hat, we have to be stuffing them in. The national R&D goals for aeronautics and the recently issued agenda for achievement outline numerous opportunities for dramatic advances that could reshape aviation by the turn of the century. They also provide a cohesive framework for focusing national efforts.

Space technology receives a real and much needed shot in the arm in this budget request, and I will do everything I can to ensure that it is only the beginning of a new trend towards a more realistic investment in research and technology. Of course, the important thing is that this subcommittee has continued to support the aeronautics and space research program over the years, and I am grateful for that. I thank you, Mr. Chairman. That concludes my prepared remarks. I would be happy to answer any questions.

Senator RIEGLE. Thank you, Dr. Colladay. Let me just say to my colleagues I think we will go with five-minute time periods because we have two other witnesses to hear today and other members I think, will come as we go along.

Give me your impression—are you convinced that we still lead the world in aviation, and if so how do you measure that, and how do you see the dynamics of our position vis-a-vis the rest of the world? Are we extending our lead? Is it shrinking? What is happening there?

Dr. COLLADAY. It is a dynamic situation. I think it varies according to the civil sectors in aviation that you look at. Where we have traditionally led, and I think we do have a competitive advantage, is when we combine advanced technology into novel, innovative aircraft configurations. We led in the high bypass turbofan, the wide bodied aircraft. We can do it again with the propfan or the unducted fan concept that GE is pursuing, with tilt rotor and with X-wing rotorcraft. When we assemble advanced technology in those areas into new configurations, which this country is so good at, we do lead. There is not so rosy a picture, however, when you look at the threat in rotorcraft across the board. We need to do more there.

In general aviation and commuter aircraft where the market penetration is dominated by foreign competitors, it is not as much an issue of technology, although we are concerned about that. I have an advisory committee working on the very issue of how can we better transfer the technology out of our aeronautics program into the general aviation community, but there are other factors in that sector that impact the competitive picture.

I think it is a question of being able to run faster. In the competition, the gap is narrowing across the board.

Senator RIEGLE. When you say the gap is narrowing across the board, again, I want to understand a little better the dynamics. Is it that the rest of the world is moving faster than we are? Are we slowing down? I mean, why is this gap narrowing?

Dr. Colladay. I think in part the gap is narrowing because the rest of the world is running faster. And I think from the standpoint of the U.S. industry we need to make sure that the technology that is the key to that competition gets transferred from the laboratory to the industry. I think we are. I think the pipeline is filled with technology that is in the process of being transferred in the subsonic transport area—for example, the competition between our industry and Airbus.

In hypersonic flight, I think we clearly have a lead through the Aero-Space Plane Program. And that is going to cascade technology into applications which we have not even begun to fully appreciate yet. I think the one area that we need to really concentrate on right now is the supersonic cruise area.

Senator Riegle. What are the international dynamics there? What are our competitors doing in that area in comparison to ourselves?

Dr. Colladay. The Europeans have a strong base of understanding and technical capability gained through the Concorde program that makes them very formidable competitors. I think we have leapfrogged many of the technologies that were incorporated in Concorde in propulsion and variable cycle engines. We are making good progress there in high temperature composite materials and in supersonic laminar flow. We need to do more. But those are the technology areas that I think we need to push.

Senator Riegle. Are you focusing extra resources of NASA in that area now?

Dr. Colladay. We initiated this year, Senator Riegle, a major industry technology study contract and market and economic studies in order to lay out the right program for the country to undertake and to guide the technology efforts. We started that this year. We are building up in a limited way some of the technologies associated with supersonic cruise to get ready for the results of those studies which I think are going to paint a clear picture of what we need to do.

The budget in the aeronautics program for supersonic cruise has increased from approximately $3.0 million in fiscal year 1986 to two years later, $13.5 million. So, we have increased it 350 percent but I would characterize it as a get ready to do something significant budget.

Senator Riegle. Thank you. We will have some other questions. Senator Danforth.

Senator Danforth. Dr. Colladay, I do not like to be the guy who is forever complaining or beating a dead horse with respect to last year's tax bill, but I do seem to do a little bit of that.

We in Congress were particularly tough on our aerospace industry in the tax bill in a variety of different ways: repealing the investment tax credit, cutting back considerably on the completed contract accounting method, making depreciation less generous, and cutting back and sunsetting the research and development tax credit.

Then looking at the aeronautical R&D budget for NASA, it appears that it is basically a stand-pat budget in research and development.

Dr. **Colladay**. In absolute terms, it is essentially a stand-pat budget if you compare 1987 to 1988. But I would point out, there is another way that it is appropriate to look at that budget. It sounds like I am making excuses but I am not: I just want to point out that the run-out of the 1987 budget to 1988 was $10 million below the request in 1988, and so we had a growth in the aeronautics R&T of $10 million and in the Aero-Space Plane, which is really primarily an aeronautics effort, it is $10 million higher than the run-out of last year's request. So, in total, it is a modest increase over last year.

Senator **Danforth**. Pretty close?

Dr. **Colladay**. That is right.

Senator **Danforth**. How would government aeronautical research and development compare to that of private sector research and development?

Dr. **Colladay**. We feel that the investment that NASA makes in R&D is more long-term and higher risk than typically is the character of industrial investments in the R&D.

Senator **Danforth**. How do the total amounts compare, though?

Dr. **Colladay**. Industry R&D investments in private profit funds are higher by a considerable amount.

Senator **Danforth**. A multiple?

Dr. **Colladay**. In the combined.

Senator **Danforth**. Large multiple?

Dr. **Colladay**. No, I don't think it is a large multiple. In the areas that are typical of the space R&D or the aeronautics R&D that we work, I would say a factor of two, probably, not a large multiple.

Senator **Danforth**. Do you think the sale of aircraft is one of the few areas where we are still doing well in international trade? Obviously, competitiveness is the big buzzword this year.

Do you think that it is a mistake to hit the aircraft industry hard in the tax bill, have essentially a stand-pat budget for NASA in aeronautical R&D spending and then expect to maintain our advantage in international trade, particularly against subsidized foreign competitors?

Are we just heading on a certain decline? We are not spending what we should on research. We are running into unfair foreign competition in aircraft sales, very predatory competition, I would say, in the case of Airbus.

Are we doomed, in your opinion, as a result of all this or are there things we can do to regain our advantage?

Dr. **Colladay**. I do not think we are doomed at all. It is one of the strong positive balance of trade sectors in this country. It is one of the bright spots.

Senator **Danforth**. We are almost doing our best to dull it, are we not?

Dr. **Colladay**. Well, I think that is unfortunate. I would like to see us provide strong support for one of our success stories and not be looking at it in a number of years, and wringing our hands that we let it go the route of so many other industries that were once competitive.

We derive our competitive advantage through technology, and I think we are doing a good job in targeting those high payoff areas in R&D that can lead to an improved competitive position of our industry, but what we do now does not affect that situation until ten years from now, in the mid-1990s. The lead time on technology is at least that long. The situation we face today is a result of investments made ten years ago.

Senator DANFORTH. Thank you, Mr. Chairman.

Senator RIEGLE. I share Senator Danforth's concern in that area. Senator Bentsen.

Senator BENTSEN. Thank you very much, Mr. Chairman.

Dr. Colladay, when there is a surplus in trade of approximately $10 million per year in aircraft over the last ten years, obviously it is a matter of great concern to all of us what happens in the way of research, to our being competitive.

What we have seen the Concorde is financial disaster, and a piece of technological elegance that cannot be afforded. So, what I am asking you is, in what you envision, for the aerospace plane, do you look on it as a commercially feasible venture, ultimately?

Dr. COLLADAY. Embodying all of the technology in the Aerospace Plane in a single commercial vehicle of hypersonic cruise capability, I think is rather remote, at least in the near term. I think the——

Senator BENTSEN. What is near term?

Dr. COLLADAY. Twenty or 30 years for the first application of the Aerospace plane technologies. The government will more than likely be the first customer, either as a launch vehicle or as a military strategic vehicle, and that is traditional.

Senator BENTSEN. Well, we have a limitation on time. Let me pursue that further. How do you determine between the Defense Department and NASA, how you divide up research in this area so you don't have duplication or an overlapping?

Do you sit down together and work out priorities and say, we are going to research this one and you research that one, or is it a mishmash or is it without consultation?

How is it done?

Dr. COLLADAY. It is done with a lot of consultation across the board in the Aeronautical R&T area, in the Aerospace plane per se. That needed to be such a tightly coordinated program that it in fact had to be joint.

Senator BENTSEN. That is an 80-20 cost sharing, is it?

Dr. COLLADAY. Over the life of the entire program, both phases, that is correct, 80-20 with a higher share of NASA funding in the technology development phase that we are in now, with the Air Force funding becoming more dominant in the development of the X-30 vehicle. That is the same relationship that we had in the X-15 program too.

Senator BENTSEN. I was involved as a board director in the competition between Boeing and Lockheed on the SST, and then came along here in the Senate and voted against the program because I could not see the commercial feasibility in the near term, be it 20 years or so. Twenty years later, it is still not commercially feasible, so that is why I asked the question like that.

I want to see the breakthroughs. I think it is terribly important that we stay up front in technology and that we make the great leaps forward, and your agency is one that delves into that kind of objectives, but, I also want some reality and some pragmatism, trying to leaven that. That is why I am asking the question.

Dr. **Colladay**. Well, many of the technologies, Senator Bentsen, that are driven by the goals of the Aerospace plane, will have application in the nearer term than the time frame I mentioned. Advanced materials alone that are required for the Aerospace plane will find their way into early application as soon as those materials are available.

Senator **Bentsen**. But insofar as other projects, how do you decide who takes this particular project and that one with the Defense Department?

Dr. **Colladay**. Coordination occurs at many different levels—we have an Aeronautics and Astronautics Coordinating Board that plans and coordinates programs between NASA and DOD, and then an Aeronautics Panel under that that reviews and coordinates all of the aeronautical R&T between the Department of Defense in 6.1 and 6.2 research, and the NASA aeronautics program.

Sometimes we do joint programs where they are co-managed. Sometimes we structure the programs to be complementary and other times we share the results, always at least sharing the results back and forth in the respective technology programs. I think they are well coordinated.

Senator **Bentsen**. Thank you, Mr. Chairman.

Senator **Riegle**. Thank you, Senator Bentsen.

Let me ask a related question to the line of discussion that Senator Bentsen has been advancing. You said earlier that commercial or commuter aircraft, if I heard you properly, was the area where foreign competition seems to have been the most extreme, and I would like you to explain that a little bit, the degree to which that is due to targeting and government subsidy and help, things of that kind, versus just superior craft of one kind or another.

What is driving that, and what might be done to deal with it?

Dr. **Colladay**. It is not, Senator Riegle, so much a case of technology in that area as it is a combination of foreign government support and the economics from our manufacturers' viewpoint that cause them to shy away from getting into that market.

The manufacturing liability that raises the purchase cost of those vehicles has impacted general aviation in which the commuter segment tends to be most aligned with in manufacturing side and has had a tremendous impact on the purchase cost of vehicles. General aviation aircraft ten years ago, liability coverage was a minor part of the cost of the vehicle. It is to the point now where in GA aircraft it is $50,000 to $100,000 of the purchase cost, and that has had a big impact as well.

Senator **Riegle**. Let me ask you to do this, in the interest of time. I think the question that was raised earlier about whether or not we are ever going to see an SST type aircraft be commercially feasible, we are seeing the reverse of that, and that is that airline deregulation and a lot of other things are driving more and more reliance on commuter type aircraft and people moving around that way and so forth, and we are seeing that in the sales volumes area and so forth.

I would like you to do an assessment for the record of what are the factors that are bearing on that problem, and try to give it some percentage weight, the degree to which financing help from foreign governments is part of it, targeting is part of it, other purchase incentives or what have you, how much is liability insurance, how much is technology, whatever.

I would like you to lay it out so we can really understand the dynamics of that, and if you can give us some sense too of the scale of the dollars we are talking about over time, some kind of a trend line showing as to what is going on there, because that seems to me to be a vital business area and I do not want to see us pushed out.

I would like to see us, able to function there and if we have got some impediments we must deal with, I would like to know what they are and see if we can make some headway.

Dr. COLLADAY. I will do that.

[The following information was subsequently received for the record:]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, DC, March 17, 1987.

Mr. LLOYD L. BEASLEY, JR.,
Printing Clerk, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, DC.

DEAR MR. BEASLEY: Enclosed is the edited transcript from the February 26, 1987, hearing at which Dr. Colladay testified on NASA's Aeronautics and Space Technology FY 1988 budget request.

The assessment of the factors affecting the commuter aircraft sector of the aeronautics industry requested by Senator Riegle on page 26, will take approximately eight (8) weeks. It will include economic and technical factors, both foreign and domestic, and will provide a judgement weighting on their relative importance. We will submit this report by May 1, 1987.

Sincerely,

LYNN W. HENINGER,
Director, Congressional Liaison Division.

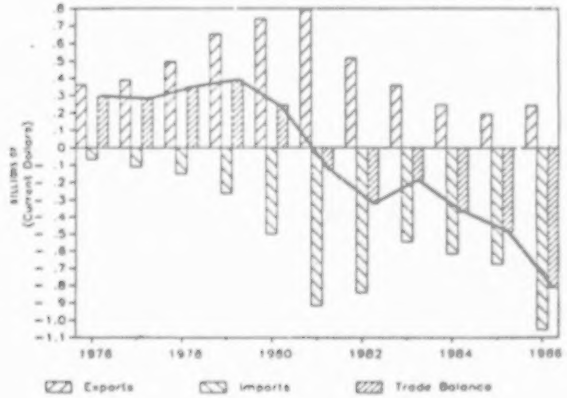
ASSESSMENT OF FACTORS AFFECTING THE U.S. COMMUTER AIRCRAFT INDUSTRY

On February 26, 1987, during Congressional hearings on NASA's FY 1988 Budget, the U.S. Senate Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation requested that NASA make an assessment of the factors affecting the commuter aircraft sector, including economic and technical factors, both foreign and domestic, and provide an indication of their relative importance. This brief report is in response to that request.

Synopsis

Information from the U.S. Department of Commerce shows that the imports of general aviation and commuter aircraft into the U.S. have increased considerably over the last 10 Years (Figure 1). In 1981, the trade balance shifted from a favorable to an unfavorable position.

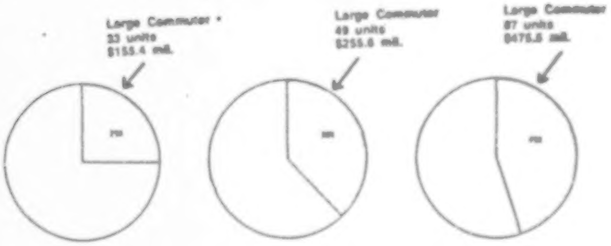
U.S. GENERAL AVIATION AND COMMUTER AIRCRAFT TRADE



SOURCE: U.S. DEPARTMENT OF COMMERCE FIGURE 1

Much of the growth in the value of the imports is due to increased purchases (Figure 2) of the larger commuter aircraft with passenger capacities over 20 seats, manufactured solely by foreign firms.

TOTAL VALUE OF GENERAL AVIATION IMPORTS



1984 = $611.7 MILLION 1985 = $672.7 MILLION 1986 = $1,053.5 MILLION

* LARGE COMMUTER IS OVER 20 SEATS and INCLUDES: ATR-42, BRASILIA, DASH-8
F-27, SF-340, SHORTS 360

SOURCE: U.S. DEPARTMENT OF COMMERCE

FIGURE 2

Over one-half of the large commuter aircraft produced in 1986 were imported to the U.S. (Figure 3).

SHIPMENTS OF LARGE COMMUTER AIRCRAFT 1986

	TOTAL SHIPMENTS	U.S. IMPORTS	AVERAGE UNIT PRICE OF U.S. IMPORTS (IN MILLIONS $)
ATR-42	30	7	$6.1
BRASILIA	15	13	4.5
DASH-7	1	--	–
DASH-8	36	18	5.6
F-27	17	10	5.7
SAAB 340	36	22	5.0
SHORTS 360	24	17	4.6
	159	87	

ESTIMATED VALUE OF LARGE COMMUTER MARKET
IN 1986 = $666 MILLION TOTAL SHIPMENTS

SOURCE: U.S. DEPARTMENT OF COMMERCE FIGURE 3

The demand for these larger commuter aircraft is expected to continue in order to satisfy the strong growth in commuter traffic which is forecast by the Federal Aviation Administration to double in passengers by 1998 relative to 1986. While many foreign aircraft companies have chosen to concentrate on this market segment, there are no U.S. companies that are producing commuter aircraft with over 19 seats. There are many contributing factors to this situation, of varying levels of importance.

The rapid growth in commuter airline travel resulting from airline deregulation occurred at the same time that the U.S. general aviation manufacturers were doing very well in the more lucrative and seemingly more stable general aviation personal and business aircraft market. As a result, most U.S. manufacturers were reluctant to develop new commuter aircraft for a market which was deemed more unstable and uncertain. Most commuter airlines at the time were small with limited resources for purchasing new commuter aircraft. Aircraft certification regulations were in a state of flux. And the future of airline deregulation was unclear. The new and rapidly expanding commuter airlines were faced with a limited selection of aircraft available to meet their needs. Previously owned aircraft such as the Beech 99, Handley Page HP-137, Mohawk 298, and Nord 262 were in short supply and the commuter airlines turned to the Swearingen Metro, deHavilland DHC-6 Twin Otter and Dash-7, Embraer EMB-110 Bandeirante, and the Shorts 330. With encouragement from the commuter airlines, Beech renewed production of the Beech 99 as the C-99 derivative and launched the development of a new 19 passenger Beech 1900.

Many foreign manufacturers were encouraged by the success of the deHavilland Dash 7 and Shorts 330 and launched development programs for new 30-to 60-passenger aircraft. These included the deHavilland Dash 8, Embraer EMB-120 Brasilia, AerospatialeAeritalia ATR-42, and CASA-Nurtanio CN-235. The only new aircraft developments for this size involving U.S. companies were the Commuter Aircraft Corporation CAC-100, Ahrens AR-404, and a joint program between Fairchild and Saab on the SF-340. During 1982, two complaints were filed with the U.S. International Trade Commission by U.S. manufacturers (the Commuter Aircraft Corporation and Fairchild-Swearingen) alleging that the U.S. industry was being materially injured by the importation of subsidized foreign aircraft. These cases were unsuccessful. The Commission determined that there was no reasonable indication that the U.S. industry was materially injured or threatened with injury or that the establishment of an industry in the U.S. was materially retarded by reason of these imports. As a result of these findings, no countervailing duties were imposed on the imported aircraft. It is significant that all the new foreign commuter aircraft projects have continued to completion while the U.S. efforts, including the Fairchild involvement in the SF-340, have failed.

Even though the large commuter market is growing, there is currently no U.S. manufacturer developing a new generation commuter aircraft. The strong dominance of the large aircraft segment of the commuter market by foreign manufacturers is not being challenged by U.S. manufacturers.

There are many important competitive factors that bear on this situation. These factors are discussed in detail in three recent comprehensive studies: Competitive Assessment of the U.S. Commuter and Business Aircraft Industry by the United States International Trade Commission, March 1986; A Competitive Assessment of the U.S. General Aviation Aircraft Industry by the U.S. Department of Commerce, International Trade Administration, June 1986; and The Competitive Status of the U.S. Civil Aviation Manufacturing Industry by the Manufacturing Industry Panel, Committee on Technology and International Economic and Trade Issues, National Research Council, National Academy Press, 1985. This report relies heavily on the information and findings contained in these detailed studies, updated where appropriate. Based on this information, a summary assessment of the primary factors currently affecting U.S. manufacturer decisions with regard to the development of a new commuter transport are shown in the following table, with a judgement of their relative importance. This assessment also represents a consensus of the representatives from the U.S. general aviation industry, government, and universities participating in a recent meeting of NASA's Aeronautics Advisory Committee's Ad Hoc Review Team on General Aviation.

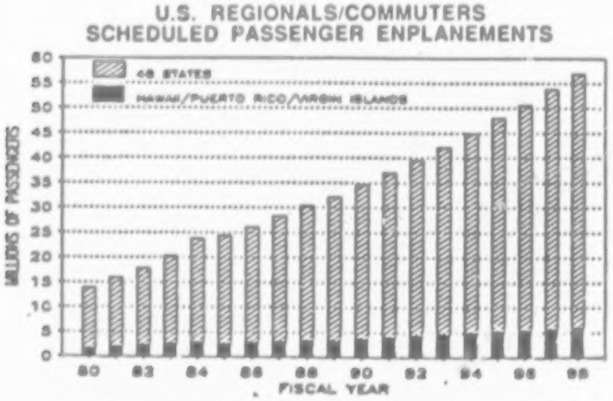
FACTORS AFFECTING U.S. MANUFACTURER DEVELOPMENT OF A NEW COMMUTER TRANSPORT

FACTORS	RELATIVE IMPORTANCE
• Foreign Government Development (Capital Investment and Risk Reduction)	Very High
• Foreign Government Sales Support (Financial and Internal Purchasing)	Low
• Liability Insurance Costs (Upward Pressure on Prices)	Moderate
• Current Market Competition/Fragmentation (Perception of Achievable Market Share)	High
• Technology (Ability to Beat the Competition)	High

The remainder of this report provides background information and discussion of these factors as well as the reasons for the judged assessment of relative importance.

Background on the U.S. Commuter Airlines

Prior to deregulation, the most significant factor affecting the growth of the U.S. commuter industry was the conversion to large jet aircraft by the large commercial carriers. The cost of operating large jet aircraft was such that traffic to and from many smaller communities proved insufficient to justify continued regular scheduled service. Airline deregulation accelerated this process as the larger certificated air carriers abandoned many of these smaller markets to concentrate on higher-density and longer-haul markets, markets to which the large jet aircraft were best suited. Commuter airlines grew rapidly as they picked up these routes using smaller, propeller-driven aircraft. Commuter airline traffic has grown from 4.3 million passengers in 1970 to 26.1 million passengers in 1986, and this is estimated to grow to 56.9 million in 1998 (Figure 4).



SOURCE: FAA AVIATION FORECAST FY 1987-1998 FIGURE 4

These smaller commuter/regional airlines currently conduct one-third of all scheduled airline flights. Detailed information on regional/commuter airline growth is contained in the report FAA Aviation Forecasts, Fiscal Years 1987-1988, FAA-APO-87-1, February, 1987.

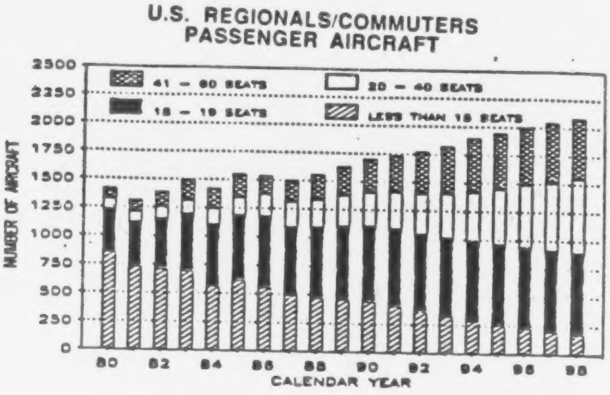
The commuter airline industry has developed and grown in an unrestricted environment. Given the freedom of entry and exit from the market, there were at one time almost 600 different carriers which reported commuter passenger traffic to Civil Aeronautics Board and the Department of Transportation (DOT) between 1970 and 1986. The growth of the industry can be attributed in large part to the role it plays as a feeder of traffic to the larger commercial airlines. The significance of the role is reflected in the growing number of markets served by commuters and in the increasing size and sophistication of aircraft operated by these airlines.

Two years ago, during 1985, the commuter airline industry began another period of transition involving some new factors which will determine the industry composition in the future. These factors include a stabilization in the number of markets served by the large jet operators, a continued decline in the number of regional/commuter operators, and a proliferation of code-sharing agreements (use of the same airline code designation for passenger reservation purposes) with large commercial air carriers.

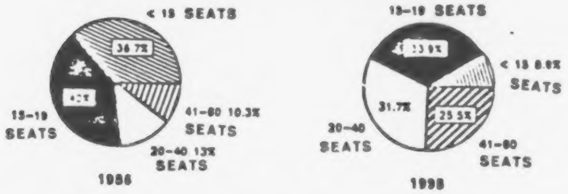
As of September 1986, approximately 150 commuter airlines were reporting to DOT, compared with the high of about 250 in 1981. While the number of carriers has declined, the average size of today's commuter has grown considerably since deregulation. The growth in size is evidenced by the fact that the average number of passenger enplanements per carrier grew from just over 30,000 in 1970, to over 48,000 in 1978 (6 percent average annual growth), but leaped dramatically to 180,000 by 1986 - an average annual growth of 18.0 percent. This trend toward industry concentration and increased size is expected to continue.

In 1984, only 17 of the top 50 U.S. commuter/regional airlines had code-sharing agreements with major airlines, now 45 of the top 50 have code-sharing agreements. And, already a new, more significant factor has emerged. This new factor is equity interest in, or outright ownership of, regional airlines by the large major airlines. Equity interest in regional/commuter airlines underscores the importance of a good feeder system for a major air carrier. Within two years it is likely that most U.S. commuter airlines will be owned by large U.S. airlines. Equity interest or ownership of commuter/regional airlines by major airlines results in a loss of the entrepreneurial, independent status of these airlines, but it should provide greater access to the financial resources necessary for new aircraft and equipment acquisitions.

The growth of the regional/commuter airline industry is also reflected in the growth and changing composition of the commuter aircraft fleet (Figure 5).



PERCENT BY AIRCRAFT SEAT SIZE



SOURCE: FAA AVIATION FORECAST FY 1987-1998

FIGURE 5

In 1980, aircraft with less than 15 seats accounted for 60.9 percent of the total commuter fleet. By 1986, this category's share of the total fleet had declined to just under 37 percent. This change is the result of the cessation of operations by many smaller commuters and the conversion by the larger carriers to new, faster aircraft better suited for the markets served through the growing feeder/code-sharing agreements with the large airlines. This trend is expected to continue and the number of aircraft in the "less than 15 seats" category is expected to decline by 67 percent between 1986 and 1998, and to account for just under 9 percent of the total fleet in 1998.

The "15-19 seats" category represents the largest portion of the U.S. regional/commuter airline fleet, increasing from 25.8 percent in 1980 to 40 percent in 1986. While this category is expected to continue to account for the largest portion of the fleet, its relative share of the total fleet is expected to decline to just under 34 percent in 1998. The largest growth in the regional/commuter fleet is expected to be in the "20-40 seats" and the "greater than 40 seats" categories. In 1980, these categories accounted for only 7.1 and 6.1 percent of the total fleet, respectively. By 1986, the "20-40 seats" category had increased to 13.0 percent and the "greater than 40 seats" category to 10.3 percent. By 1998, these two categories are expected to account for over 57 percent of the U.S. regional/commuter airline fleet, 31.7 percent in the "20-40 seats" category and 25.5 percent in the "greater than 40 seats" category. Aircraft in the "20-40 seats" category are expected to increase from 200 aircraft in 1986 to 662 in 1998, an average annual increase of 10.5 percent. Aircraft in the "greater than 40 seats" category are expected to increase from 159 aircraft in 1986 to 532 in 1998, an average growth of 10.6 percent. This trend toward larger aircraft will increase the average seating capacity per aircraft from 20.4 seats in 1986 to 28.8 seats in 1998. The U.S. regional/commuter airline fleet is projected to grow at an average annual rate of 3.2 percent through 1998, increasing from 1,538 aircraft in 1986 to 2,087 in 1998.

Foreign Government Development Support

Most foreign manufacturing competitors are backed by governments whose goals are full employment, technology development, and the generation of foreign currency in addition to commercial gains. Consequently, these competitors are likely to stay in a selected market, even if large expenditures are required to sustain extended product development and production operations during periods of very slow sales. While such actions would be both unsound and impossible for a private manufacturing company, they can make long-term social and economic sense for individual countries. This difference constitutes a formidable competition for privately financed U.S. companies.

The following table from the International Trade Commission shows the foreign manufacturers and the extent of ownership by their respective governments.

COUNTRY	FIRM	EXTENT OF GOVERNMENT OWNERSHIP
Brazil	Embraer	51 percent
Canada	Canadair	100 percent
Canada	deHavilland	None 1/
France	Aerospatiale	100 percent
France	Dassault	51 percent
West Germany	Dornier	4 percent by a State Government
Great Britain	Pilatus-Britten Norman	None, privately owned
Great Britain	British Aerospace	None 2/
Indonesia	P. T. Nurtanio	100 percent
Israel	Israel Aircraft Industries	100 percent
Italy	Aeritalia	100 percent
Italy	Partenavia	None, but a wholly owned subsidiary of a 100 percent Government owned firm
Italy	Piaggio	None, privately owned
Japan	Mitsubishi Aircraft International	None, privately owned
Netherlands	Fokker	None, privately owned
Northern Ireland	Short Brothers	100 percent
Spain	CASA	71 percent

1/ deHavilland was purchased by Boeing Corp. in December 1985 from the Canadian Government. Prior to this date the firm was 100 percent owned by the Government of Canada.

2/ British Aerospace was 49.3 percent owned by the British Government prior to April 1985.

Foreign government investment in aircraft programs is considered in the public interest because the aircraft industry is viewed as a good means of earning foreign currency and improving overall industrial development. Direct government assistance frequently involves production loans or actual grants. In 1982, for example, Canada provided Can $38.6 million followed by Can $6.2 million in 1983 for the development of the Canadair Challenger 600/601 business aircraft. Aerospatiale of France received $134.6 million during 1981-1984 for the development of the ATR 42 commuter aircraft. And the Dutch government has provided both loans and grants to Fokker for development of the Fokker 50 and 100. Government financing during the development phase of new commuter aircraft is extremely important, as the inherent risks involved and the long time before financial recovery can either preclude private financing or make it very costly. Such assistance lowers the barriers to entry into the industry, reduces fixed costs, and increases profitability. Higher profit level may also enable foreign firms to increase research and development efforts, invest in state-of-the-art technology, and further increase their competitiveness.

Government production assistance also allows continuation of aircraft manufacturing far beyond what could be sustained by normal market forces. For example, the Australian Nomad commuter aircraft was in production for 18 years with total sales of only 180 aircraft before its manufacturing was stopped in 1982. Tax incentive programs also help finance foreign commuter aircraft manufacturing. Companies are often exempted from paying duties on important raw materials and subcomponents used in manufacturing.

In contrast, the U.S. Government does not provide direct production subsidies or grants to manufacturers of commuter and business aircraft. The only form of financial support is through tax benefits, available to all U.S. industries, that provide some assistance in research and development and capital investment. The Economic Recovery Tax Act (ERTA) of 1981 provided a business tax credit of 25 percent of the incremental investment in research and development expenditures over a 3 year base period. The ERTA also provided other tax incentives to spur new investment in production facilities. The Tax Reform Act of 1986 replaced the ERTA with a business tax credit of 20 percent for incremental research expenses. Qualifying expenses are limited to innovative research of a technological nature paid or incurred by January 1, 1989. Additionally, the Foreign Sales Corporation (FSC) Program is a U.S. tax deferral system that benefits domestic exporters. The FSC program allows firms to establish special subsidiaries that can exempt a portion of their export income from Federal Income Tax.

Since many of the foreign manufacturers of commuter and business aircraft are the only small aircraft manufacturers in those countries, their governments generally purchase applicable aircraft from those manufacturers. These government purchases provide stability to the aircraft production run. Military purchases by their respective countries have proven very significant for the CASA C-212 and the CASA-Nurtainio CN-235. The Canadian, British, and Brazilian governments have also been very important customers for their respective commuter manufacturers.

The U.S. government has purchased both U.S. and foreign-built commuter and business aircraft for military use. Still, the U.S. government procurement of these aircraft is very small compared with other aerospace purchases and with overall commercial production. In 1984, the U.S. government purchased less than 5 percent of the total U.S. manufactured commuter and business aircraft shipments.

Foreign Government Sales Support

Particularly during a period of high commercial loan interest rates, government-supported financing of commuter aircraft at low rates can be a very important factor in aircraft sales. Brazil was one of the countries that offered Government sponsored financing at low rates to assist with U.S. sales of the Bandierante during 1980-84. No or minimal downpayment, below-market interest rates, lengthy loan terms, and deferral of interest or principal payments for several years have been offered by some foreign export agencies. These financing incentives have the effect of reducing the initial cost of acquiring commuter and business aircraft and reducing their operating cost. An International Trade Commission study done in 1982 noted that a 1 percent difference in interest rates could offset as much as a 3 percent price differential or a 2 percent difference in fuel efficiency.

In January 1986, tentative agreement was reached on general aviation aircraft financing which complements the Arrangement on Guidelines for Officially Supported Export Credits, providing guidelines for official government export financing on the sale or lease of new aircraft. The agreement established the following terms: the interest rate will be at matrix or commercial interest reference levels; for turbine powered aircraft with 30 to 70 seats, the export financing shall be for a maximum 10 year term; other turbine-powered aircraft shall be for a maximum term of 7 years; and other aircraft shall be for a maximum term of 5 years.

Foreign government involvement in export promotion is also used to help increase industry sales. Promotion may be as simple as embassy assistance in market research or representation of the industry at trade shows. However, although public documentation of the arrangements are not available, several governments have reportedly offered inducements that only central government could provide for export sales. Incidents of granting of foreign aid or export licenses in unrelated commodities, as well as offset and countertrade offers, have occurred.

The United States also offers some export promotion programs to assist domestic business in selling their products abroad. The U.S. Department of Commerce, International Trade Administration, organizes overseas commercial exhibitions of domestic products and conducts trade missions and sales seminars. The ITA collects and publishes opportunities abroad and assists U.S. firms in competing for major foreign projects. The Export-Import Bank of the United States provides direct loans, loan guarantees, and loan insurance to public or private foreign buyers to finance U.S. exports.

Liability Insurance Costs

The sharp increases in U.S. commuter and business aircraft product liability costs is another important factor in the decline in sales. In 1985, product liability premiums for general aviation aircraft totaled nearly $135 million. Product liability insurance can now constitute up to 30 percent of the purchase price of an aircraft. In contrast, in 1962, the average cost of product liability insurance for a manufacturer was less than 1 percent of the airplane's price. Although the majority of the suits filed against U.S. manufacturers involve small, private aircraft, the manufacturers must absorb their liability expenses over all units sold, regardless of type. In addition to contributing to the higher aircraft prices, the issue of product liability has resulted in the withdrawal of products from the market as well as a lack of innovative new products.

Foreign manufacturers of commuter aircraft do not contend with the same high product liability insurance costs as our domestic manufacturers. This is partly because it is very difficult to recover damage claims from companies located overseas. Also, since most foreign manufacturers do not have a long history of producing smaller aircraft, these manufacturers do not have as high a level of product liability insurance to add into the price of their other aircraft.

Legislation intended to reform U.S. product liability tort, law while treating injured parties fairly, was supported by every major general aviation consumer group and received wide bipartisan support in the House and Senate. However, it failed to pass in the 99th Congress.

Current Market Competition/Fragmentation

The U.S. regional/commuter airline fleet has grown from 1,047 aircraft in 1978 to 1,806 in 1986. The largest increase during this period was for aircraft with seating capacities from 31 to 40 passengers. The number of aircraft of this size increased from 22 in 1978 to 143 in 1986. The growth in the size of the commuter fleet is expected to continue in response to commuter passenger forecasts which predict traffic to double from 1987 to 1998, from 28.3 million to 56.9 million passengers. In 1986, the commuterregional airlines ordered nearly $1 billion in new aircraft, an amount equal to the total orders over the previous five years. Where there were once very few manufacturers of 15 to 60 passenger commuter aircraft, the rapid growth of this market since U.S. airline deregulation has resulted in many more competing suppliers.

There are currently 6 manufacturers, including two U.S. manufacturers, of commuter aircraft with seating capacities between 15 and 19. These include the British Aerospace Jetstream 31, Fairchild Metro, Beechcraft B-1900, Embraer EMB-110 Bandierante, Dornier 228, and deHavilland Twin Otter. The BAe Jetstream 31 is a Garrett TPE-331 powered derivative of the original Handley Page HP 137 Jetstream which was powered by Turbomeca Astazou engines. During 1986, the Jetstream 31 received 63% of the 19 passenger pressurized turboprop market. As of April 1987, there were 154 total orders for the aircraft, of which 126 had been delivered. Of these totals, 114 were U.S. orders, of which 87 had been delivered. Introduced as the Swearingen Metro in 1971, the Fairchild Metro now accounts for over 350 aircraft in scheduled service in 19 countries and provides nearly 20% of the U.S. commuter fleet. Since its introduction in 1968, 239 Beech 99's have been delivered. The Beech 1900, introduced in 1984, has accounted for 68 aircraft deliveries. Embraer has delivered 468 EMB-110 Bandierante's, first introduced in 1973. By the end of 1986, Dornier had delivered 100 Dornier 228's. As of March 1987, sales of the Dornier 228 stood at 117 total orders with 46 options. Since 1965, deHavilland has delivered over 830 Twin Otters. The only announced development of a new 19 passenger commuter is the Embraer EMB-123, scheduled for production in 1990.

Where there was once only one new 30 to 40 seat aircraft model available, there are currently five manufacturers (all foreign) producing aircraft in this size range. These include the Embraer EMB 120 Brasilia, Saab-Scania SF-340, CASA/IPTN (Indonesia) CN-235, deHavilland Dash 8, and Shorts 360. First introduced into service in August 1985, the Brasilia has achieved 91 firm orders, 110 options, and 31 deliveries. The Saab-Scania SF-340, certificated in June 1984, currently accounts for 77 deliveries. Since certification in 1986, 113 CASA/IPTN CN-235 aircraft have been ordered, about one-half as military aircraft. By the end of 1986, deHavilland had obtained 94 orders for the Dash 8 series 100 aircraft, with 40 deliveries. Introduced in 1980, the Shorts 360 now accounts for 120 aircraft deliveries. There are currently 119 Shorts 330's in service. In April 1987, Dornier announced the design of a new 30 passenger commuter, designated the Dornier 328.

The 40 to 60 seat commuter market currently involves four manufacturers (all foreign). These include British Aerospace with the ATP, Aerospatiale-Aeritalia with the ATR-42, Fokker with the Fokker 50, and deHavilland with the Dash 7 and Dash 8 series 300. Certification of the British Aerospace ATP, which currently has 5 orders, is planned for July 1987. The Aerospatiale-Aeritalia ATR 42 was introduced into service at the end of 1985. Currently, the aircraft has 81 firm orders with 40 delivered. A stretched version, the ATR 72 is scheduled for certification in May 1989. With current firm orders for 39 and 12 options, first deliveries of the Fokker 50 are scheduled for mid-1987. The Fokker 50 replaces the F27 after 786 deliveries of that aircraft. The deHavilland Dash 7, STOL transport, introduced in 1975, now has 109 deliveries. In March 1987, deHavilland rolled out the Dash 8 series 300, a 50-56 seat stretch version of the Dash 8.

The development of these commuter aircraft represents a considerable investment by the manufacturers. Spreading the market among this many competing models results in considerable competition for sales and increases the risk of achieving economic success for anyone considering entering this market. In order to consider developing a new aircraft, it is essential that an aircraft be sufficiently superior to the competition to obtain a sufficient market share and insure a large enough production run to cover the development costs. Two manufacturers are currently developing, or considering the development of, new aircraft in this market. These include the Embraer EMB-123, an advanced technology 19 passenger aircraft, and the Dornier 328, a new 30 passenger design. The development of these aircraft indicates that technology can still provide major improvements over current aircraft.

Technology

In the aircraft industry, technology is a very important factor in determining an aircraft's competitive position in terms of performance, operating cost, passenger comfort, and initial cost. A continuous program of research and development is necessary to maintain a successful aircraft manufacturing business. Because of the infusion of Federal funds, government supported manufacturers are often able to continue research and development programs, often relatively independent of market sales. Government loan guarantees also reduce the cost of borrowing to finance research programs. Many of the foreign manufacturers have very close ties to their national research agencies, similar to the relationship between the U.S. industry and the National Aeronautics and Space Administration. The following table from the International Trade Commission shows some of these organizations.

COUNTRY	RESEARCH ORGANIZATION
Japan	National Aeronautical Laboratory, National Research Institute
West Germany	Dt Forschurges - v Versuchanstalts uft - v Ravnfiahrt, Ministary of Research & Technology
France	National Office of Aerospace Research
Brazil	Aeronautics Technical Center, Instituto Technologico de Aeronautica
United Kingdom	Royal Aircraft Establishment, Department of Trade and Industry
Netherlands	Netherlands Agency for Aerospace Programs
Spain	Instituto Nacional de Industria

Although technological leadership is not in itself sufficient for success in the marketplace, the emergence of effective international competition increases its importance. There are still some very important, attractive opportunities for further advances in aerodynamic design, controls, structure, and propulsion that can provide greater fuel efficiency, lower noise, greater utility, and lower operating costs. In most of these technologies the United States still enjoys a lead. However, that lead is shrinking and our competitors possess the skills and commitment to challenge our leadership in virtually every field.

In the late 1970's and early 1980's, NASA conducted a series of studies to define the advanced technologies that could be applied to develop improved commuter transport aircraft. The results of these studies are described in Small Transport Aircraft Technology NASA SP-460, published in 1983. As described in this report, the studies identified several opportunities for advances in aerodynamics, propulsion, structures and systems that could be pursued to develop future aircraft with improved economics and passenger acceptance. Development of these technology advances were estimated to provide aircraft structural weight reductions of 10 to 15 percent, aerodynamic drag reduction of about 10 percent, and the reduction in fuel consumption of about 40 percent compared with current (1985) aircraft. The areas of technological improvement for small transports are similar to those for large aircraft, but some unique design and technology requirements result from the smaller size, lower weight, lower wing loading, shorter stage length, and lower altitude operation of commuters.

In aerodynamics, climb performance is as important as cruise performance. Additional technology development is required in the areas of advanced wing design (including low-drag airfoils and improved high-lift systems) tailored for commuter aircraft requirements, interactions of configuration components (e.g., wing, body, and tail/canard) for both conventional and unconventional designs, and propulsion systems integration (including slipstream effects for propeller-driven aircraft). The attainment of laminar flow (naturally or in combination with a low-cost active system) could provide significantly improved aerodynamic performance.

In propulsion, overall propulsion system efficiency, different duty cycles, and smaller engine component sizes result in different goals and constraints. Since many of the benefits of advances in large engines do not apply to the smaller powerplant, additional research is required to address small turbine engine components and propeller technology appropriate to commuter aircraft needs.

In structures, smaller sizes, lower load intensities, and minimum gage limitations mean different trade-offs in airframe design and in the utilization of materials, particularly for composites. Structures research is needed to emphasize composite materials and processes that are more applicable to lower cost production than the present systems, even at some sacrifice in the strength-to-weight ratio gains achieved by current systems.

In systems, those which enhance ride quality and safety in the low altitude operating environment while increasing dispatch reliability take on increased importance. Research in this area can contribute to reduced structural loads and improved ride quality by enabling the development of suitable active gust load alleviation systems incorporating the latest state-of-the-art advances in electronics, sensors, and controls. Research in flight management and performance management with associated displays could provide a reduction of pilot workload and enhance safety.

NASA's aeronautics research program is addressing most of the necessary technology areas. The development of new aeronautical technology requires dedicated effort by research specialists working over many years. Maintaining momentum in the effective aeronautical R&D complex that includes NASA, DOD, private industry, and the FAA is crucial to continued U.S. technological leadership. With fewer new aircraft being developed, there is an increasing concern about the transfer of technology from basic research to product development. NASA conducts basic and applied research and technology development in key areas of science and engineering. Private companies incorporate properly validated new technology into new aircraft.

Future Outlook

The U.S general aviation and commuter aircraft manufacturers are extremely concerned about the decline in their sales and competitiveness in domestic and foreign markets in recent years. During this period, the value of overall domestic shipments fell, as did exports, capacity utilization, and employment. U.S. commuter and business aircraft manufacturers have responded to the severe decline in general aviation sales by closing down 8 facilities and laying off more than 17,000 employees during 1980-1984. Some corporate owners have also attempted to sell off their general aviation divisions.

Currently, one ameliorating factor in the balance of trade resulting from the importation of foreign manufactured commuter aircraft is the large content of U.S. manufactured components. The U.S. has the largest, most developed aerospace component industry. These subcomponents represent an important portion of the final cost of imported aircraft. Major parts, such as engines, avionics, and environmental control systems are almost always of U.S. origin. The U.S. content of foreign-built aircraft, however, may decline as foreign industries become more vertically integrated in their aircraft manufacturing.

The rise of the dollar from 1981 to 1984 had a significant impact on the international competitiveness of the U.S. commuter aircraft industry. For example, in 1981-82, foreign buyers in Mexico experienced a 130 percent increase in cost due to the strength of the dollar. The rise of the dollar also increased the cost for U.S. aircraft in Europe. Similarly, foreign firms experienced a gain in exchange rates, allowing their aircraft to become more cost competitive. Recently the dollar has sharply declined against foreign currency which should make U.S. products more competitive abroad.

It appears that the future competitiveness of the U.S. commuter aircraft industry may be limited to an extremely narrow and declining segment of the market. The domestic industry does not produce any commuter aircraft for more than 19 passengers. Even U.S. involvement in the 19 passenger market may decline if Fairchild's current negotiations with Aeritalia for the sale of Fairchild Aircraft, manufacturer of the Fairchild Metro, are successful. Since the majority of future commuter aircraft purchases are expected to be for airplanes capable of transporting 30 to 50 passengers, foreign producers will dominate the future market. The Boeing Corporation's recent purchase of the Canadian commuter aircraft producer, deHavilland, constitutes the only U.S. entry in this market.

A new entrant to the commuter aircraft manufacturing industry faces substantial barriers to entry. The commitment to build an aircraft for the commuter market involves a considerable investment of time and capital. According to industry sources, approximately $250 million to $500 million is required in nonrecurring costs alone to design, produce, certify, and market new models. The magnitude of this investment varies considerably, however, depending on factors such as the size of the airplanes, initial production and sales, extent of product improvements, individual program productivity, and the amount of risk assumed by subcontractors. The bulk of the expenditure must be made early in the program, well before any appraisal of the eventual success of the venture can be made. Additionally, there is a lengthy time period between the actual selling of the aircraft and the point at which the manufacturers are able to recoup their costs. Approximately 3 to 5 years are required in order for an established aircraft manufacturer to perform all the necessary steps to develop a new commuter or business airplane. The time period required for a new entrant would most likely be even longer.

The changes occurring in both the domestic and international environments pose some great challenges for the management of civil aircraft development and manufacturing. Historically the large air transport manufacturers have excelled at producing technically proficient aircraft that were well matched to market needs. Although it sold and serviced airplanes worldwide, the industry operated from an exceedingly powerful domestic base and faced little foreign competition in any market. It dealt with a short list of customers whose characteristics were well known. The challenge for the manufacturers of commuter aircraft is more direct. They face the more immediate threat of international competition in both domestic and international markets, and they do not occupy the position of global dominance enjoyed by manufacturers of large transports. Furthermore, until recently they faced little in the way of competition. Consequently, they have had little exposure to the exigencies created by facing new, well-designed products in their market.

Commuter transports present a difficult situation for U.S. manufacturers. Until recently the U.S. commuter market did not attract the development of specialized aircraft to serve it. Other countries did have such requirements and had developed the needed aircraft. With deregulation leading to increased growth in domestic regional airlines, foreign manufacturers have moved to capitalize on this opportunity. U.S. manufacturers face a dilemma: their own product lines are not extensive; the U.S. market is relatively open to competitors while many foreign markets are closed; and foreign manufacturers--typically supported in some form by their governments--are active in the field and frequently have been for many years. In addition, it is evident that these foreign manufacturers intend to hold onto this market. Many are actively involved in developing stretched derivatives of their aircraft, and two, Embraer and Dornier, are developing all-new advanced technology 19 and 30 passenger aircraft.

Senator RIEGLE. Thank you. Now, with respect to industry concerns, Dr. Krone in his testimony today points to several things: level of funding, the area of federal contracting, the philosophy concerning the use and support of government wind tunnels, the philosophy concerning internal and international cooperation, and the restrictions on the publishing of basic research.

I would like you to comment on these industry concerns and others that you may have heard and indicate what steps you are taking to deal with these kinds of problems and to fulfill the goals that were established in the 1985 OSTP report.

Dr. COLLADAY. Let me take facilities first. It is a very important area and one of the principal responsibilities that NASA has is to make facilities available for advanced research as well as development support to industry.

The aeronautical facilities that we have in our inventory now have an average age of 32 years. That age, combined with the fact that the demand for those facilities and new aircraft developments is projected to go up substantially in the future, leads me to be extremely concerned about the state of our facilities that are really a national resource in aeronautics and that go back and many years.

I have started a major assessment of the national requirements and needs for those facilities across the industry, including the DOD contractors, and put in place in this budget a beginning step towards addressing improved productivity of data acquisition systems and increasing the throughput of test articles through the wind tunnels. That is one area that I am stepping up to and I am concerned about.

Senator RIEGLE. Let me just ask you on that, is there a request in your proposal that directly goes to wind tunnel per se, whether it's maintenance, enhancement, modernization, replacement, whatever, and if so, how much is that and where can we find that in the budget?

Dr. COLLADAY. It is in the R&T base, Senator Riegle, and in fiscal year 1988 we have put in place four and a half million dollars for the data acquisition systems and improved productivity. Right now, for the facilities' possible rehabilitation and modernization is part of the study that will be concluded later this year.

Senator RIEGLE. So, there is no money in for that at the moment?

Dr. COLLADAY. Not specifically as a result of that study. Over the last ten years or so, though, we have put more and more emphasis on rehabilitation and modernization of our existing facility capability as opposed to all new capability because of the importance of taking care of what we have.

Senator RIEGLE. Why should that money come out of the research side of things? Why shouldn't facilities upgrading and modernization come from someplace other than research money?

Dr. COLLADAY. The rehabilitation and modernization does come out of the Construction of Facilities budget. The enhancement of productivity and data acquisition systems is in the R&D budget and that is in the category of operations. But the capital investments are out of the Construction of Facilities budget.

Senator RIEGLE. I am just going to raise one other issue, and then we will have questions both from me and from other colleagues that we are going to ask you to answer for the record.

I am pleased to see the initiative in civilian space technology which you spoke about earlier, and we were very interested to see how that comes along because we had something that there is a keen interest on in here, I have and other Members of the Committee have.

So, let me thank you for your testimony today. We will have other questions for you for the record.

Dr. COLLADAY. Thank you, Senator Riegle.

Senator RIEGLE. Thank you very much.

[The statement follows:]

STATEMENT OF DR. RAYMOND S. COLLADAY, ASSOCIATE ADMINISTRATOR FOR AERONAUTICS AND SPACE TECHNOLOGY, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and members of the subcommittee, I am pleased to present NASA's FY 1988 Aeronautics, Transatmospheric, and Space Research and Technology (R&T) budget requests which reflect a growing commitment to R&T and its importance to NASA's mission and U.S. competitiveness. For FY 1988, NASA is requesting $375 million for Aeronautics R&T, $66 million for Transatmospheric R&T, and $250 million for Space R&T, as shown in Figure 1.[1] I will briefly discuss the program accomplishments and plans in each of these program areas.

AERONAUTICS

NASA's Aeronautics Research and Technology program continues to be focused on long-term, emerging technologies aimed at maintaining United States leadership in aviation and enhancing U.S. industrial competitiveness. The Aeronautics R&T budget request of $375 million in FY 1988 continues positive efforts begun last year and enables us to move forward in several new areas. Within the nearly constant overall level, the successful completion of activities in several programs has allowed augmentations in high-temperature engine materials technology and facilities support. Now that the Numerical Aerodynamic Simulation (NAS) facility is operational, we have also consolidated the funding for its operation into the NAS budget line.

The high-temperature engine materials program represents a consolidation and expansion of the previous hot-section technology and ceramics for turbine engines programs, which were originally planned for completion in FY 1989. Progress in high-temperature materials presents an opportunity for dramatic improvements in engine thrust-to-weight ratio and efficiency by allowing increases in turbine inlet temperature (Figure 2) without cooling of the turbine blades. Such improvements are particularly important for supersonic cruise and short takeoff and vertical landing (STOVL) vehicles. Research will be directed at ceramics, ceramic composites, metal matrix composites, and carbon-carbon materials for high-performance gas turbine engines building on the work that has been ongoing in the R&T Base.

NASA is responsible for a large number of major aeronautical facilities that are essential to maintaining U.S. superiority in aeronautics. These facilities are experiencing, and will continue to experience, significant increases in demand to support the new aircraft development programs, to conduct experimental research on new concepts, and to provide the experimental data base necessary to validate new computer prediction methods. Many of the major wind tunnels that are considered critical in satisfying this demand are old and in need of rehabilitation and modernization. A wind tunnel efficiency enhancement initiative will be directed at increasing the productivity and quality of the test data for these critical wind tunnels—with improvements in data systems, displays, and instrumentation. In addition, we have initiated a comprehensive national assessment of projected wind tunnel utilization requirements and the state/adequacy of existing major NASA wind tunnels to meet these requirements. This assessment will form the basis for developing a time-phased, prioritized plan for providing new capability and modernizing, rehabilitating, and, if appropriate, removing from service selected wind tunnels.

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[1] The figures referred to throughout this statement were not reproducible.

On July 21, 1986, initial operations began with the Numerical Aerodynamic Simulation (NAS) facility at NASA's Ames Research Center. Construction of the new building to house the NAS is also now complete (Figure 3), and the entire complex will be dedicated on March 9, 1987. The capabilities of the NAS are already in high demand and there are currently over 190 remote users throughout the U.S., tied in by the NASA Program Support Communications Network (PSCN). Through this broad user network, the NAS computational power is being applied to perform many complex aerodynamic, structural, and materials calculations that were not previously possible. For example, the first full flow-field solution for viscous 3-dimensional flows about complete aircraft configurations is now posssible. The particle streamline traces from a representative calculation for an F-16 aircraft configuration are shown in Figure 4. Similar calculations are also being performed to examine the internal flow field of high-temperature turbine engines.

The use of computational fluid dynamics (CFD) in modern aircraft design is a dream that has become a reality. Past aeronautical achievements could not explore all of the dimensions of fluid mechanics during the design process. As a result of our newly acquired ability to numerically simulate complex flows, aeronautical research and design capability has increased dramatically and the horizon of problems and applications that can now be considered continues to surpass technology projections.

The FY 1988 Aeronautics R&T budget will allow NASA to continue the strong record of accomplishment in its aeronautics programs directed at subsonic, supersonic, and hypersonic/transatmospheric technology. The program is consistent with the goals established in the Office of Science and Technology Policy, Aeronautical Policy Review Committee report, "National Aeronautical R&D Goals: Technology for America's Future," and the eight-point action plan outlined in the recently published "Agenda for Achievement."

In subsonic vehicle technology, NASA's pioneering efforts in developing the technology for new fuel-efficient, high-speed propellers have led the way for General Electric and the rest of the industry. The Unducted Fan (UDF) concept, developed by the General Electric Company, is a unique counter-rotation turboprop design that couples the propeller blades directly to the turbine to eliminate the need for gears. The UDF engine successfully completed ground testing under NASA sponsorship during August 1986. Flight tests are currently being conducted by General Electric with the engine installed on a modified Boeing 727 aircraft (Figure 5). Additional flight tests will be conducted later this year on a Douglas MD-80 aircraft. Also during the past year, a Gulfstream GII aircraft was modified (Figure 6) for the Propfan Test Assessment (PTA) program by adding an advanced single-rotation, propfan installation on the left wing. Flight testing of this system will begin this year which will provide detailed information on structures, aeroelastic response, and acoustics. The results of the PTA flight tests, combined with the UDF tests, will provide a valuable technology base for high-speed propeller and engine design that can be used as a basis for future industry decisions on advanced turboprop systems, whether they are single- or counter-rotation or tractor or pusher configurations. In FY 1988, emphasis will continue in ground-based research on source noise, cabin noise, turboprop installation aerodynamics, and advanced blade structures for both single- and counter-rotation propellers.

Major strides have been made in developing the technology for aerodynamic drag reduction using natural laminar flow, laminar flow control, and turbulent drag reduction methods. During the past year, flight testing was conducted with an F-14 aircraft modified with natural laminar flow gloves installed on the upper-surface of the variable sweep wing (Figure 7). These experiments extend our understanding of boundary layer transition as a function of wing sweep angles and flight speeds representative of future transport aircraft.

Flight tests of a modified NASA Lockheed JetStar with active laminar flow control leading-edge gloves have demonstrated that laminar flow can be maintained in a realistic airline environment without any undue maintenance burden. Future research efforts are now concentrated on hybrid laminar flow (HLFC), which combines active laminar flow control and natural laminar flow to obtain significant drag reduction benefits with minimum system complexity. Over the next two years, the work in HLFC will focus on flight research at high Reynolds numbers on a large transport aircraft. Flight tests will provide basic aerodynamic data for evaluating the concept at full scale for actual operating conditions.

The skin friction drag reduction benefits predicted for riblets (tiny longitudinal grooves on the surface) were measured in detailed flight experiments performed at the Langley Research Center on the fuselage of a Learjet aircraft. These tests measured a 6- to 8-percent reduction in friction drag. This is the same riblet technology that was licensed to the 3M Company and used to reduce drag on the "Stars and Stripes" in the America's Cup competition.

In rotorcraft technology, the X-Wing vehicle offers the potential for combining the vertical takeoff and landing capability of a helicopter with the high cruise speed capability of a fixed-wing aircraft. The program to develop this technology reached a major milestone last year with the competition and rollout of the NASA/DARPA RSRA/X-Wing (Figure 8) aircraft. The vehicle is in final checkout in preparation for start of the flight test program at the Dryden Flight Research Facility in March of this year.

In support of the FAA and as a part of NASA's research efforts in aviation safety, major full mission simulation study of the human factors aspects of the new Traffic-alert and Collision Avoidance System (TCAS II) was conducted at the Ames Research Center during the last year. The TCAS II provides information in the cockpit, illustrated in Figure 9, on the position and threat potential of up to three aircraft in close proximity to the subject aircraft. Commercial airline crews flew full simulated mission scenarios in which collision avoidance was required. The results have provided information on display effectiveness and pilot response. Additional NASA research in aviation safety, being conducted jointly with the FAA, is directed at developing an airborne windshear detection system and an investigation of the effects of heavy rain on aircraft aerodynamic performance.

In supersonic vehicle technology, considerable progress was made in the past year in high-performance aircraft. Flight tests were conducted of the variable camber, mission adaptive wing on the NASA/Air Force AFTI/F-111 aircraft (Figure 10). Test results for the in-flight manual pilot adjustment phase of the program have demonstrated improvements of 25-30 percent in mission range and 15 percent in sustained maneuvering G's when compared to the F-111 with a supercritical wing. Testing with an automatic variable camber control system will begin this year.

Flight research is continuing on other programs which offer the potential for major improvements in aircraft performance. NASA has modified a Navy F/A-18 aircraft to a configuration for conducting high angle-of-attack flight research. This research aircraft provides the focus for a coordinated analytical, wind tunnel, simulator, and flight research program to develop and refine the design tools and predictive techniques to enable controlled maneuvering flight at post-stall angles of attack. We have recently initiated a joint U.S./U.K. cooperative program directed at advanced short takeoff and vertical landing (STOVL) technologies. System studies and ground-based analytical and wind tunnel model investigations are underway to identify the most promising aircraft and propulsion concepts that may lead, at some future date, to flight testing of an advanced supersonic STOVL research aircraft.

During the past year, major high-speed transport studies were initiated with both Boeing and McDonnell Douglas that will examine the market opportunities, identify the most promising aircraft concepts and cruise speeds, and define the technology requirements for advanced high-speed (supersonic to hypersonic) transport aircraft. These studies will help define the research and technology efforts that would be pursued to insure that the United States industry is in a strong position to develop future high-speed transport aircraft that are commercially viable and environmentally compatible.

NASA's aeronautics research related to hypersonic/transatmospheric flight in the areas of computational fluid dynamics, materials, and propulsion has successfully made the transition to the National Aero-Space Plane program. The program will continue to pursue long-term technology advancements in aerodynamics and propulsion that can apply to a broad range of future hypersonic aircraft.

TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

The emergence of technology in hypersonics R&T in NASA and in other U.S. government laboratories and industry has achieved the promise for a new class of aerospace vehicles which can travel at hypersonic speeds up to orbital velocities using airbreathing propulsion and airplane-like operations. These advances include demonstrated performance of airbreathing supersonic combustion ramjet (scramjet) engines; advances in high-temperature, lightweight materials and structural concepts; and the availability of supercomputers such as the Numerical Aerodynamic Simulation capability at the NASA Ames Research Center. Launch vehicles based on this technology would be able to take off and land on conventional runways and fly directly into orbit, providing an important option for space transportation in the next century. Alternatively, a hypersonic aircraft could provide point-to-point intercontinental travel as a high-speed transport or military surveillance vehicle. As mentioned earlier, NASA has initiated major high-speed transport studies with industry that include consideration of such aerospace vehicles.

NASA has joined with the Department of Defense (DOD) to conduct the National Aero-Space Plane (NASP) program. This program is a combination of vehicle design and component development and testing and a supporting technology maturation effort. It is an outstanding example of the blending of aeronautics and space technologies and has enlisted a highly skilled national team from government, universities, and industry. The NASP program is a primary component of continued world leadership by the United States in aerospace technology.

To conduct the NASP program the NASA and DOD have formed a joint program management organization (Figure 11) that includes a Steering Group with the Under Secretary of Defense (Acquisition) serving as chairman and the NASA Associate Administrator for Aeronautics and Space Technology serving as vice-chairman. The steering group provides policy, guidance, and broad programmatic direction. The program is being implemented through the Program Management Office located in Washington, D.C., and Joint Program Office located at Wright Patterson Air Force Base. NASA has established a NASP Office in OAST to interface with this joint program structure.

The NASP program is comprised of the three phases shown in Figure 12. The first phase, which dealt primarily with concept feasibility, was completed in 1985 and provided the confidence to proceed with the program last year. The second phase, which deals with technology development, is currently underway and scheduled for completion at the end of 1989. This phase includes five competing airframe contractors, three competing propulsion contractors, and a highly focused technology maturation effort to support the contractors. The five airframe contractors are Boeing, McDonnell Douglas, Lockeed, General Dynamics, and Rockwell. The three propulsion contractors are Pratt & Whitney, General Electric, and Rocketdyne. Rocketdyne is participating in the program using its own funds. The competitive contract efforts include conceptual and preliminary design, component development, and testing. The technology maturation effort includes research at NASA centers, other government laboratories, and industry efforts in generic areas supporting all of the contractors. The decision to proceed to Phase 3 will depend on an assessment of technology readiness in 1989 by the NASP Steering Group. Phase 3 would involve the design and development of the X-30 research vehicle and the flight test program.

NASA is requesting $66 million for Transatmospheric R&T, to be combined with $18 million from the Aeronautics and Space R&T base budgets for a total of $84 million in FY 1988, as its share of the joint DOD/NASA National Aero-Space Plane program. The DOD is requesting $241 million and the combined request is shown in Figure 13. The combined NASA and DOD request has increased in FY 1988 to support the change in the contracted ekfforts from concept to preliminary design and the initiation of component fabrication and testing. It also reflects a continued strong technology maturation effort to insure the timely development of critical technologies.

Significant technical progress is being made in a number of critical technology areas, including propulsion, materials and structures, and computational fluid dynamics. Specifically, tests conducted in the NASA Langley Research Center propulsion wind tunnel have demonstrated the successful operation of a candidate ramjet engine under conditions corresponding to a flight Mach number of 3.5 (Figure 14). In addition, good agreement has been achieved between the tunnel test results and analytical calculations for the engine cycle.

A hypersonic engine model was also tested at the CALSPAN Shock Tunnel at a flight Mach number of 10 (Figure 15). This model is a derivative of the NASA Langley Research Center airframe integrated scramjet design. Tests included combustion with varying fuel/air ratios and varying fuel injection angles and the use of downstream fuel injection along the engine walls to reduce wall heating and skin friction. The tests demonstrated good combustion efficiency and resultant thrust for the short combustor section used. The tests showed, as predicted, a marked reduction in skin friction with film cooling. This reduction in skin friction is important in achieving the required engine system performance.

A number of different hypersonic inlet concepts are being evaluated in the program, such as the one recently tested in the NASA Ames Research Center arc heated wind tunnel (Figure 16). In these tests, the free stream flow conditions were Mach 8 at simulated altitude of 200,000 feet and temperatures of 1400 degrees Fahrenheit.

High skin temperatures underscore the importance of developing lightweight, high-temperature materials for aerospace plane structures. This is one of the most critical challenges in the program. It is an area in which NASA has considerable interest and expertise and is working closely with DOD laboratories and industry. Significant efforts are underway at the NASA Lewis Research Center in the development of fiber-reinforced composites for airframe and engine applications and at the NASA Langley Research Center in the development of carbon-carbon materials and advanced metal matrix composites for airframe applications.

Another important materials area being considered involves rapid solidification rate (RSR) processing. In this process, small droplets of molten alloys are spun off a disk and through a cool helium gas, cooling the droplets at rates up to a million degrees per second. This rapid cooling freezes in the alloy characteristics which would be lost in a slower cooling process. The resultant powder is then compacted under high pressure into sheets and other shapes. The resulting alloy can have up to twice the strength and stiffness of conventional alloys and retains its properties to much higher temperatures.

RSR titanium alloys being developed by this process are being further improved through the addition of fibers which will further increase the material strength and stiffness. The material shown in Figure 17 was created by plasma deposition of RSR titanium onto silicon carbide fibers. The resulting advanced metal matrix composite has two times the stiffness and one and one-half times the strength of the conventional RSR titanium alloy.

At the Ames Research Center, the 3.5-foot hypersonics research tunnel has been reactivated to support the NASP program. A hypersonic model is being used to obtain experimental data to validate some of the latest computational fluid dynamics codes. Figure 18 shows the model in the wind tunnel at flow conditions of Mach 7.4. Some initial CFD calculations have been completed to predict the Mach number contours on the surface of this model. These results are shown in Figure 19. Such calculations will allow the analysis and prediction of hypersonic vehicle aerodynamics and aerothermodynamics at flight conditions where ground test facilities are inadequate.

During FY 1988, two or three of the original five airframe contractors and two of the propulsion contractors will be working toward completion of Phase 2. Thse contractors will be identified by a competitive selection process near the end of FY 1987. Also, during FY 1988, two engine test facilities, which are being modified to allow propulsion system testing up to Mach 8, will begin operation. Emphasis will continue in the technology maturation area on the testing of subscale scramjet engine concepts, on the development of advanced materials and structural concepts, and on the validation of CFR codes. Special emphasis will be placed on boundary layer transition. The ability to predict transition accurately is critically important in heat transfer analyses for NASP vehicles. In addition, research on integrated controls will be initiated.

Overall, the NASP program is making good technical progress. The program goals are still valid, though extremely challenging. An integrated DOD/NASA management team is in place and functioning well. Confidence is high and the NASA/DOD team will continue moving aggressively to achieve the NASP goals.

Space R&T

Our request this year for the Space Research and Technology program reflects a reevaluation of NASA's technological capability to sustain leadership in space. We are especially aware of lessons learned from the past and of the role of technology in leading to a strong national civil space program in the future. Advanced technology is a prerequisite to sustained leadership, providing reliable options for the scientific and human exploration missions of the future. In FY 1988, we propose to initiate the Civil Space Technology Initiative to begin the restoration of the technology base to enable high priority future programs.

The United States civil space program began with the recognition that heavy research and technology investments had to be made to support a national commitment. Early investments paid large dividends. New technology and new concepts were necessary before the United States proceeded with vigor into space. The concept of the high aerodynamic drag entry configuration and the heat shield for the Apollo Command Module, the development of cryogenic tankage and propulsion systems for the Saturn launch vehicle, and the development of life support systems and space suits were all required to assure the first successful human step on the moon by a United States astronaut. Then, in the mid-to-late 1960's, up-front research flights to verify the concept of low lift-to-drag ratio entry configurations, new reusable entry materials, and the technology for reusable propulsion systems were critical to the subsequent development of the Space Shuttle.

After peak investment in the early 1960's, the NASA Space Research and Technology budget fell so precipitously that within 10 years we dropped from a 6-percent level of investment to one-third of the investment rate when the Nation made its commitment to leadership in space. We find ourselves now with demands on our technology and a need for additional budgetary resources to meet them.

During this same period, investments abroad in France, Italy, Germany, Japan, China, the Soviet Union and other countries have increased greatly. Competitive products across a broad range of space endeavors have been, and are being, developed through extensive research investments. These foreign products range from launch vehicles, to commercial communications satellites, to science missions, and now to the prominent Russian space station. Our aerospace industry, the highest of the few remaining high-technology segments of the U.S. economy with a positive balance of trade, is seriously threatened with increased competition. As a result, our favorable trade balance in this area has diminished significantly. What was once an unquestioned area of U.S. preeminence—the civil space program—is now increasingly a field with shared leadership.

Even without this growing evidence of foreign competition, it is clear that our technology base is deficient. It no longer leads with options for the future—it chases problems. A few examples illustrate the point. The Space Shuttle Main Engine development has outpaced the technology program for reusable engines that should support it. We face an information lag and a data glut. In the Space Station era, the data generated will exceed 10 terabits per day, greater than all of the written information in the Library of Congress. The SP-100 space nuclear power program, itself a technology program, had to take a conservative approach to the thermal conversion system because of unacceptable risk with more efficient conversion systems. We need to start development of new launch vehicles but do not have the technology ready. Spacecraft payload capacity is unnecessarily limited because we have not developed the technology to lower the power, propulsion, and structural mass fraction. There are parts of the spectrum we cannot exploit for remote sensing because we have not done the instrument development research. The examples go on. Our expectations for the future exceed what our current technology base can deliver.

Every recent study on the U.S. civil space program has pointed out the need for increasing research and technology investments in space. The National Commission on Space; a Space Science Board study, "Twenty-Year Forecast of Space Science, 1995-2015"; and a joint DOD/NASA study in response to a National Security Study Directive on technology required for future space transportation systems, all strongly call for a greater national investment in research and technology to support a wide spectrum of applications.

The last year was a period of tragedy, reflection, and rebuilding. It continues to be a period of recovery for NASA, reconstituting Shuttle capability, maintaining Space Station momentum and resolving the science mission backlog. But, if recovery is to be lasting, we must start now to rebuild the technology base. The Civil Space Technology Initiative (CSTI) that we are proposing in FY 1988 will reorient and enhance the Space Research and Technology program. The Space R&T budget request of $250 million includes a $70 million augmentation as a part of CSTI.

In 1988, we propose restructuring the Space Research and Technology program. In the transformation from the FY 1987 budget, the program has been restructured into two parts. The first part is the R&T Base which will retain the generic discipline orientation of the past. The second part, CSTI, combines some research formerly in the R&T Base with the past systems technology programs and augmented to focus on the technology elements required to enable next-generation NASA missions. The character of each of the elements of CSTI is to provide crucial data and to verify new concepts at a sufficient level so that the technology can be considered ready to apply.

CSTI focuses on research in propulsion, vehicle, information systems, large structures and control, power, and automation and robotics (Figure 20). The CSTI elements were selected on the basis of leadership strengths, expertise, facilities, missions, and availability of conceptual data and studies from past R&T Base research. The CSTI major thrusts, as shown in Figure 21, are research in technologies for safe and efficient access to space, for earth-orbiting operations, and for future science missions.

In transportation, launch vehicle propulsion research will be aimed at reusable, high-performance engines for next-generation vehicles. A new booster technology program will develop options for both hybrid and pressure-fed propulsion systems; and, an aerobraking flight experiment will demonstrate use of the atmosphere to slow an orbit transfer vehicle returning to low Earth orbit at high velocities.

Earth-orbiting operations capability will be enhanced through a continued and expanded effort in automation and robotics. The research emphasis includes autonomous systems for control of multiple subsystems in future spacecraft, launch system software to replace routine, labor-intensive activities, and robotics for remote assembly, repair and servicing of space vehicles.

Supporting technology for science will include research in large structures and their control, large segmented reflectors for future observatories in space, sensor research for earth observations and astrophysics, and data research for onboard processing for large data-demanding systems.

Transportation.—In earth-to-orbit propulsion, we will continue, in cooperation with NASA's Office of Space Flight, to assemble the LOX/hydrogen test-bed engine using Space Shuttle Main Engine (SSME) hardware. The test-bed engine will be used to validate internal computational fluid dynamics codes; to verify advanced long-life, fault-tolerant component designs; and to demonstrate diagnostic sensors and health monitoring instrumentations. Although the program will support the ongoing SSME advanced development program, its primary objective is to provide the data base and analytical techniques for future high-performance, reusable LOX/hydrogen, LOX/hydrocarbon, and dual fuel engine developments.

For over 10 years, the NASA R&T Base program in hydrocarbon propulsion has been building an understanding of ignition, combustion stability and heat transfer through analyses and laboratory experiments. In FY 1987, the budget for research in hydrocarbon propulsion was doubled. In FY 1988, CSTI research will continue laboratory scale testing and will begin efforts to test large-scale high-pressure combustors (Figure 22).

The objective of the booster element of CSTI is to evaluate two alternatives (the pressure-fed liquid bipropellant and the solid-liquid hybrid) to the solid rocket motor for future transportation applications. Hydrocarbon propellant selection, combustion stability, pressurization system and materials compatibility studies will lead to a series of firing tests to verify pressure-fed booster performance predictions. The hybrid booster technology will establish solid fuel formulation options, ignition, and internal surface buring characteristics, and oxygen delivery techniques. The experimental verifications will result in performance parameters which could be used in future designs with the two alternative booster systems.

Our studies indicate the advantages of reusable, space-based Orbit Transfer Vehicle (OTV) for operations between low Earth orbit (LEO) and geosynchronous Eearth orbit (GEO). Application of the aerobrake concept of the OTV on return to LEO has the potential for increasing the payload by a factor of two. As shown in Figure 23, the aeroassist test vehicle is taken to low Earth orbit by the Shuttle, released, and accelerated downward into the Earth's atmosphere to a velocity of 33,000 feet per second which simulates a return from geosynchronous orbit. The aerobrake maneuver is performed at approximately 250,000 feet about the Earth's surface and the vehicle flies back to low Earth orbit where it will rendezvous with the Shuttle for return to Earth.

Key aerobrake technologies to be flight tested and demonstrated have been studied for a number of years in the R&T Base. Uncertainty exists over the total heat load these types of vehicles will experience as well as on the control and stability of the vehicle. A new computational method for predicting aft-body flow field impingements and heating and a thermal protection system has been developed and verified in wind tunnel tests in 1986. Advanced aerobrake materials must be capable of repeated reentry cycles after unfolding to the appropriate aerodynamic configuration.

Operations.—Mission studies have shown that high-capacity power for utility-like systems are essential for future Earth orbiting space stations, lunar and planetary transportation and bases, and high-performance propulsion systems for outer planet transport vehicles. Nuclear systems are expected to play a key role in meeting future power and propulsion needs. The ongoing joint DOD, DOE and NASA SP-100 space nuclear power program is in the ground development phase with the objective of demonstrating a space compatible nuclear reactor sysem and a companion conversion system using a passive thermal to electric device system with 3- to 4-percent conversion efficiency. In CSTI, we will augment ongoing research on the Stirling cycle dynamic thermal to electric power conversion system. The objectives are to establish the feasibility of a five-fold increase in the amount of electric power that can be generated from an SP-100 size reactor and a doubling of its power-to-weight ratio.

The ongoing Automation and Robotics program has been incorporated into the CSTI program in FY 1988. The objective of this research is to exploit the potential of artificial intelligence and telerobotics to increase the capability, flexibility, and safety of space and ground operations while decreasing associated costs.

The robotics element of CSTI, which is the ongoing Robotics program carried forward without change, has the specific objective of reducing the time and level of human supervision from direct human control to teleoperations and eventually to high-level, goal-oriented supervision with minimal human intervention. In FY 1987, the preliminary design and development of the space robotics demonstration facility with a two-arm manipulator will be completed. As shown in figure 24, the robot will acquire, de-spin, and service a spacecraft model with two cooperating, track-mounted robot manipulator arms. A third arm with a television camera supplies vision for the robot system. Two recent accomplishments were the establishment of the hierarchical computer architecture which will allow artificial intelligence planners to control the robot and the completion of a prototype single-channel programmable image feature extractor which provides the real-time acquisition, feature extraction and tracking, motion stereo, stereo matching, and processing of visual images for the robot.

The objectives of the autonomous systems element are expanded from the ongoing program to include research on pre-launch and post-launch operations. Figure 25 illustrates autonomous systems research that will explore approaches to automating electrical and pneumatic functions of the Orbiter on the pad. Figure 26 illustrates application of autonomous systems for intelligent control of on-orbit Shuttle communication systems. The intent is to use actual operations as a research test-bed simulation for autonomous system concept verification.

Science.—The CSTI element in sensor technology will enable observations of terrestrial, planetary and astrophysical phenomena outside the limits of current instruments. Three activities (submillimeter technology, active laser sensors, and sub-Kelvin cooler technology) make up the sensor program. In submillimeter device research, componens such as mercury-cadmium-telluride alloy frequency mixers for heterodyne detection in the far infrared portion of the frequency spectrum have been built and operated at a wavelength of 28 micrometers. Preliminary experiments on a superconducting-insulating-superconducting mixer using a new material (niobium nitride) show promise for a mixer at previously unattainable longer wavelengths of up to 600 micrometers. This mixer concept is promising in that arrays can be made which enable simultaneous spatial and spectral imaging.

The second sensor area supports research in advanced semiconductor laser arrays. These arrays would replace unrealiable flashlamps for pumping solid state laser rods and enable active laser remote sensing systems from space. Lifetimes of two years or longer are necessary to acquire the data base for future terrestrial and planetary climatology missions. Major research advances have occurred through a Langley Research Center program in conjunction with industry and academia on enabling a titanium-doped sapphire laser to meet major mission requirements such as tuning, efficiency, and spectral purity.

The third sensor research area will establish a new capability to cool far infrared detector components to sub-Kelvin temperatures. This is required for imaging in a low thermal background such as that found looking out into deep space. Past research has verified that the concept of employing magnetic bearings in a linear Stirling cycle cooler should increase the lifetime to five years and lower the temperature of a one-stage cooler to 45 degrees Kelvin. A second-stage solid state cooler based on techniques such as demagnetization will be developed to produce temperatures below 1 degree Kelvin.

The objective of the data element, as shown in Figure 27, is to provide the technology for onboard data processing and analyses so that ground systems deal only with relevant information or restricted sets of important data. In previous R&T Base research on methods for processing high volumes (up to 50 million bits per second) of space-derived scientific data on the ground, we have provided a sound technical basis for "smart" onboard information systems. A combination of high-speed, special purpose processors and high capacity data storage devices is required if we are to avoid excessive demands on ground communications, storage and processing. The CSTI high rate/capacity data research will verify new concepts for onboard image processors to deal with massive data volumes of up to 400 million bits per second from synthetic aperture radar, visual, and focal plane instruments.

CSTI data research also includes verification of a read/write high capacity (a trillion bits) erasable optical recorder. This unit could store images for overlays and comparisons and provide buffering during periods of ground communication obscuration. Last year in the R&T Base, we took a major step in achieving the high data rates and capacity optical storage by producing a nine-element laser diode array.

Future space missions will require very large, erectable and deployable space structures for a number of future applications, such as large communication satellites, science observing platforms, advanced space station configurations, the Large

Deployable Reflector and very large baseline interferometers. These structures must provide precise surface accuracy and be very flexible because of demands for low weight and large size. Therefore, we initiated the Control of Flexible Structures (COFS) program in FY 1985 as a series of in-space experiments to provide fundamental data on structures and control concepts which cannot be obtained in ground laboratories because of gravity loading. In CSTI, we have coupled the COFS flight program with appropriate discipline activities of the R&T Base to achieve a comprehensive research activity which includes analytical methods development, component development, ground-based testing, and in-space verification. The COFS I experiment consists of a large 60-meter deployable/stowable joint-dominated truss structure, called MAST, which will be dynamically tested in space cantilevered from the Shuttle payload bay (Figure 28). The MAST is currently under development.

Future scientific space missions call for very large, very precise reflectors for telescopes and interferometers. An example is the reflector for the infrared and submillimeter astronomical observatory being considered for the mid-to-late 1990's. Current planning is for a reflector 20 meters in diameter, similar to the concept shown in Figure 29, with a surface smoothness accuracy of 1 to 2 microns. Structures of this type exist on earth, but they are very heavy with glass reflecting surfaces and massive supporting structures for stiffness. A space-based system must be stiff enough to minimize surface disturbances, must be lightweight and dimensionally stable under nonuniform heating conditions, and must be actively controlled. Furthermore, the system must be fabricated in segments for transport to orbit for assembly and operation.

In the ongoing R&T Base, we have started research on high precision, lightweight reflector panels with the goal of producing panels 1 to 2 meters across and weighing less than 10 kilograms per square meter. A small 0.4-meter panel has been fabricated which weighs only about 5 kilograms per square meter and has an average surface smoothness of about 0.5 microns. While this small scale panel surpassed goals in weight and density, the design concepts must be tailored to larger scale while ensuring for surface accuracy, space durability, and thermal dimensional stability.

The Civil Space Technology Initiative opens some exciting prospects for the future which depend on advanced technology. The initiative is founded on a decade of R&T Base research in emerging technologies and is a positive first step toward restoring our technical strength. CSTI meets identified priority needs of NASA and national programs. It is an affordable step focusing on technologies to enable advanced transportation to and operations in Earth orbit and to enable next-generation science missions. It will stimulate our staff by providing increased involvement on cutting-edge research and technology with a clear direction for the future. Our engineering universities will also be positively motivated to increase research activities supporting our future in space and to provide a magnet for new talent. Most important of all, the timing of CSTI is fundamental to providing a long-term basis for the recovery of the Nation's space program.

SUMMARY

Historically, technology has been a cornerstone of our leadership in aeronautics and space. Recent examples of the power of advanced technology are evident in the successes of the "Voyager" nonstop, unrefueled, around-the-world flight and the "Stars and Stripes" America's Cup challenger. Our aerospace industry, the highest of the few remaining segments of the U.S. economy with a positive balance of trade, faces serious competition from other nations. Other nations now dominate the world commuter-aircraft market, account for nearly half of the world sales of rotorcraft, and are achieving significant market penetration in the large commercial transport market. And, what was once an unquestioned area of U.S. preeminence—the civil space program—is now increasingly a field with shared leadership. The 1985 "National Goals for Aeronautical R&D: Technology for America's Future" and the recently published "Agenda for Achievement" outline numerous opportunities for dramatic advances in technology that could reshape aviation by the turn of the century. Achievement of these goals will lead to entirely new types of aircraft, such the National Aero-Space Plane, with vastly superior capabilities. The Civil Space Technology Initiative also opens some exciting prospects for the future. Technology advancements benefit our national economy and security, but only if we are the first to exploit them. I believe the FY 1988 NASA budget request will allow us to provide the research and technology leadership that is required in aeronautics and space. We appreciate this Subcommittee's continued support and commitment to aeronautics and space research and will continue to do our best to keep this Nation second to none in the world in aviation and space.

Thank you, Mr. Chairman. That completes my prepared testimony. I would be happy to answer questions.

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR RIEGLE AND THE ANSWERS

National Aero-Space Plane

Question 1: While speaking within the constraints of national security, where exactly are we in the development of the Aero-Space Plane? Based on your activities to date, are there any unexpected roadblocks that might impede development or deployment, or is it still too early to tell? Is the program still on schedule and will Phase III still be initiated in FY 1989? Why did NASA increase its FY 1988 level of activity compared to last year's program runout?

Answer 1: We are still early in the technology development phase or Phase 2 of the NASP program. There are five airframe companies and three engine companies involved in conceptual design of the NASP. There is also a focused technology effort underway in government laboratories and in industry supporting the contracted efforts. Although the task is very difficult, we are encouraged by the progress we are making in all areas, and we have not uncovered any unexpected roadblocks.

There has been a restructuring of the program, primarily because of the lower than requested budget in FY 1987 and Phase III is now expected to begin in the first quarter of FY 1990.

NASA's increase in FY 1988 was part of the restructured program, which includes a significant increase in the focused technology effort in FY 1988.

Question 2: What is your best professional guess when: (a) the first prototype plane will fly; (b) the first operational plane will fly; and (c) you and I, or perhaps our children, will fly from Dulles to Japan in 2 to 3 hours?

Answer 2a: The NASP program is a technology program, that includes an X-30 experimental research vehicle, or technology demonstrator, which is not a prototype vehicle. The X-30 would be designed and built in Phase III, with initial flight tests planned for 1993. Plans for prototype vehicles would depend on program results, and concurrent civil and military applications studies. Prototype vehicles would probably not fly until the 21st century.

b. Assuming the X-30 data are complete in the mid-1990's, the design of an operational vehicle, such as an orbiting aero-space plane or a military hypersonic cruise vehicle could commence before the end of the century. Introduction into service would then occur sometime early in the 21st century.

c. A hypersonic transport would tend to follow, and build upon, the experience base developed from the orbital and military aero-space plane applications.

Question 3: Is it fair to say that the primary emphasis of this program is military and strategic, rather than commercial or as a space transportation system? Based on past history, how far behind the military application does the commercial application of advanced aerospace technology development activities such as the Aero-space

Plane follow? What level of effort in the program is directed toward developing the type of life support systems required to use the Aero-Space Plane as a people mover? How does the Aero-Space Plane figure into the space transportation needs of the Nation? Is it still intended to be a cargo mover with a 100,000 pound payload capacity? Does the Aero-Space Plane benefit from the Civilian Space Technology Initiative?

Answer 3: The NASP program will develop technology for military, space and commercial transportation systems. It is a flight research program that must be conducted by the United States to establish the data base and design methodology for future vehicle applications that will evolve on the basis of National needs. A reasonable assumption is that the space transportation applications would come first.

In aircraft, civil applications often follow military systems. This was true for the jet powered swept wing transport, the high bypass gas turbine engine, and supersonic flight. In space applications the reverse is generally true. Manned space flight has been pioneered by the civil sector. The period between origination and application in many of the recent experiences is blurred by the joint military/civilian nature of complex programs.

No significant research activities are underway in life-support technology in the NASP program since the contractors are currently involved in conceptual design. Clearly, life support technology from other space and aeronautics programs will be applicable to NASP.

The NASP program is a technology development program for a new class of airbreathing hypersonic aerospace vehicles, and not a program for developing an operational launch vehicle. It should provide an option for the next generation shuttle.

It is too early in the NASP program to project potential payload weights.

The NASP program does not directly benefit from the CSTI program; however, some technologies in CSTI, such as automation and robotics, may be useful.

Question 4: Your total aeronautical research and technology budget is $375 million in FY 1988 compared to $376 million in FY 1987.

a. Why is the program losing money when this is a critical aspect of the U.S. competitive posture?

Answer 4: In order to properly assess the budget trends, there is a need to look over several years. Aeronautics was given priority in the President's FY 1987 budget with a 12 percent increase in an essentially level agency budget. Including funding for the National Aero-Space Plane (NASP), the total program was increased 25 percent. The FY 1988 aeronautics budget request is $10 million above the runout of the FY 1987 program which allows us to move forward in several new areas including high temperature engine materials and major wind tunnel test efficiency enhancement. The transatmospheric budget reflects planned expansion of the high-speed technology development in support of the NASP program.

Within the overall budget constraints arising from the difficult fiscal environment that the country faces, NASA has an outstanding, highly-productive program focused on the cutting edge technologies. Though there has been a lot of progress, there is a need for a more concerted national effort--by NASA, industry and our universities. As with the original OSTP National Goals Report, the Agenda for Achievement will undoubtedly influence NASA's aeronautics planning and future budgets.

Question 5: You mention in your statement the successful completion of activities in several programs, which has allowed you to augment your support in the high-temperature engine materials technology support.

a. What are the activities that you have successfully completed?

b. What is the level of augmentation in the high-temperature engine program, and how will this benefit the aerospace industry?

Answer 5: The funding for NASA's portion of the X-Wing Flight Research Program was completed in FY 1987. In addition, the Advanced Turboprop Program has successfully completed the fabrication and installation of a large-scale, high-speed propeller leading to initial flight tests in April 1987.

The new High Temperature Engine Materials program will be funded at $10.0 million in FY 1988. This represents a consolidation and expansion of the existing Turbine Engine Hot Section Technology ($3.8 million) and Ceramics for Turbine Engines ($2.4 million) programs. This program will focus on the development of advanced metal matrix composites, ceramic matrix composites, and carbon/carbon materials for use in advanced turbine engines. Advances in these materials promise major improvements in engine thrust-to-weight, efficiency and life which are crucial for long-distance supersonic cruise and short takeoff and vertical landing vehicles.

Question 6: One program that has been of interest to the Subcommittee is the Advanced Turboprop Program, which is nearing flight testing.

a. Is NASA essentially phasing out support for the ATP program, i.e., has the government's role ended completely?

Answer 6: The NASA ATP program is nearing the flight testing phase of the Propfan Test Assessment (PTA) aircraft. The objectives of the PTA program are to establish, in actual flight conditions, the structural integrity of the propfan, assess the propfan source noise, cabin noise, community noise as defined in the FAA's FAR-36 regulation, and enroute noise. Once the data are obtained, analyzed, and compared to predictions, NASA will continue with a supporting research and technology program focused on fundamental aerodynamic, acoustic, and structural analysis to provide a strong technology base for a broad range of future high-speed turboprop applications. This long-range technology program has been included as part of the ATP program from the start to support the U.S. aircraft and propulsion industry in the application of high-speed turboprop designs to new aircraft designs.

Question 7: It is our understanding that NASA has reduced funding for acoustics research in this area. This is the so-called near-field acoustics research so that the turboprop could be mounted on a commercial aircraft. The engine generates so much noise to people on the airplane that drastic reductions are necessary to make the engine feasible.

a. How much noisier is the ATP than, say a conventional jet aircraft engine on a B-727, for example. Is noise reduction a critical problem and potential barrier to the introduction of the turboprop to commercial aircraft? Doesn't shielding mean a huge increase in weight and a loss in the fuel efficiency that the ATP promises?

b. Is NASA reducing funding in the acoustics program? How much of a reduction, and why? Is it fair to assume that industry will fill in the funding in this area; can industry do it?

Answer 7: The data from the GE/Boeing UDF/727 flight program is now being analyzed and the PTA flight tests are just beginning. Thus, it is not yet known how much noisier a propfan may be than a conventional turbofan. However, preliminary results indicate that it is not a barrier problem, but may be a technology challenge that must be overcome. New concepts in acoustic treatments, i.e., shielding, appear promising in reducing noise without a large increase in aircraft weight.

NASA did reduce funding for cabin acoustics flight research under the PTA contract. However, NASA did initiate separate contracts with Lockheed, Douglas, and Boeing to pursue cabin acoustics research for advanced turboprops. These three contracts will utilize not only the Lockheed PTA flight test results, but also the results from the industry-funded flight test programs by Boeing and Douglas. NASA intends to continue a fundamental acoustics research effort and to be a full partner with industry in addressing propfan acoustics problems.

Question 8: What other nations are pursuing advanced turboprop designs? Is it correct that Japan has a seven year program to market a plane of this design in the early 1990's? Aren't they also working on the acoustics problem?

Answer 8: Japan, the Soviet Union, France, Germany, Italy, and the United Kingdom are aggressively pursuing propfan technology and their programs are addressing the acoustics requirements. We do not know conclusively that Japan has plans to market a propfan aircraft in the early 1990's.

Question 9: Dr. Colladay, it appears to us that NASA facilities are in need of repair or replacement. You mention that the facilities are experiencing huge increases in demand from many fronts, civilian as well as military, and that modernization is necessary to keep up with demand.

The average age of NASA's wind tunnels, the basic tool to aeronautical research and technology, is 31 years. You have several in service from the Second World War, and the oldest still in service is 56 years old.

a. Is there any request in your proposal for wind tunnel maintenance, enhancement, modernization or replacement? If so, how much, and where would I find it in your submission?

b. Your Construction of Facilities budget is $29 million, is this the wind tunnel program money? If not, where does the money come from, which account? Does the R&D budget pay for wind tunnel repair?

c. Is the problem with facilities also related to the test and measurement equipment in the tunnels, themselves? Isn't that equipment outmoded, obsolete, and inefficient? I think that the basic question is whether our facilities can handle advanced aeronautics R&D programs, such as the National Aero-Space Plane.

d. What would be your ballpark estimate on the total amount necessary to bring the aeronautics facilities up to speed, both buildings and equipment? Shouldn't the Construction of Facilities account be increased to at least begin the task of replacement?

e. What would you see as a basic investment necessary in facilities, say at a 1 percent of total value basis? How much would that be annually?

f. Is NASA relying upon the Numerical Aeronautical Simulator (NAS) to relieve the demand on the wind tunnels. Where is this demand coming from specifically? DOD?

If DOD is using your wind tunnels to such a great extent, do you receive adequate reimbursement from them, if so, how much?

Have you explored with DOD the possibility of sharing the cost of enhancement and modernization?

Answer 9a: The Aeronautics R&D budget request includes a total of approximately $70 million for facilities support in FY 1988. This includes funding for the normally scheduled maintenance, operations, and equipment upgrade. It also includes $4.5 million to modernize and improve the test efficiency of NASA's major wind tunnels to meet increasing R&D demands. With this augmentation, special focus will be placed on test instrumentation and data acquisition systems to increase the productivity of national wind tunnels. The facilities support funding is spread primarily across the Aeronautics R&T Base programs. The $4.5 million augmentation is carried under Applied Aerodynamics R&T and is described on page RD 13-13 of the Aeronautics budget narrative.

The Construction of Facilities (CoF) portion of the FY 1988 budget request includes four facility projects totaling $29.9 million. These include: modifications to the Hypersonic Propulsion Facility for Vacuum Systems at Langley Research Center ($3.1 million); construction of the Integrated Test Facility at the Dryden Flight Research Facility ($10.5 million), which is the second year of funding for this two-year project; modifications for Fan/Compressor Research, Engine Research Building, at Lewis Research Center ($6.5 million); and construction of an addition to the Research Analysis Center at Lewis Research Center ($9.8 million). The modifications to the Hypersonic Propulsion Facility for Vacuum Systems are to provide wind tunnel enhancements. The first three facility projects listed directly supports both the Aeronautics and Space R&T programs. Thirteen minor facility projects, totaling $7.3 million, address repair, rehabilitation, enhancement, and modification requirements of the Aeronautics program.

b. No, the wind tunnel program money is not in the CoF budget. NASA's Construction of Facilities program accomplishes construction of new capability, and repair, rehabilitation, and modification of existing facilities. Elements of the CoF program are discrete line items in the budget if they exceed $.75 million for repair, rehabilitation, or modification; or if they exceed $.5 million for construction of new capability. The CoF portion of the FY 1988 budget request includes four discrete facility projects totaling $29.9 million that are listed in the answer to 9a. The Aeronautics R&D budget request includes $4.5 million to modernize and improve the test efficiency of NASA's major wind tunnels to meet increasing R&D demands.

c. There is a growing need for funding to support test measurement, data acquisition, and data reduction equipment. Much of that equipment is obsolete and inefficient. We have recognized this problem and have successfully initiated a small FY 1988 augmentation to help accommodate increasing demand. Additional funds have been allocated for upgrading data systems, displays, and instrumentation to improve the productivity of our major wind tunnels.

We fully recognize the growing demands on our wind tunnels for advanced aeronautics programs. We plan to provide, within our overall budget, the future resources required to keep us current with the advancing state of the art in measurement and recording techniques. With your awareness of the problem we feel that, working together, we can be prepared to handle the future major requirements.

d. OAST agrees that the CoF account should be increased significantly. Over the years, the constraints on the CoF budget have been such that only about 50 percent of the facility needs of the Research Centers have been satisfied. For example, over the past nine years, the OAST Centers' major aeronautical facilities requirements have averaged about $75 million annually. The aeronautical portion of the approved major CoF program has averaged about $34 million annually.

We have embarked on a major national assessment of future wind tunnel utilization requirements and the state/adequacy of existing

NASA wind tunnels to meet these requirements. This assessment will form the basis for developing a time-phased, prioritized NASA plan for providing new capability and modernizing, rehabilitating, or removing current tunnels from service. When this assessment is finished later in 1987, we will have a more definitive estimate of the CoF requirements necessary to support the wind tunnel portion of the aeronautics facilities requirements.

e. OAST currently invests roughly 2 percent of the replacement value of its major aeronautical facilities in repair, maintenance, rehabilitation, modification and upgrade of those facilities. Roughly 1 percent is from the Construction of Facilities Program; another 1 percent is from the R&D in the maintenance area. We have looked at this and compared it to industry practices and find that we are considerably less than the average dedicated in the same areas as industry (4 to 6 percent). To be comparable to industry practice, we would have to at least double the level of CoF investment.

f. The Numerical Aerodynamic Simulation (NAS) facility is being used to complement the usage of NASA's wind tunnels. With NAS, computations are now achievable for complex geometries and flow conditions which have been unobtainable in the past. These computations include detailed flow-field investigations which serve to improve the effectiveness of the wind tunnel testing associated with developing advanced configurations. Wind tunnel testing is still a mandatory part of designing aircraft and detailed wind tunnel data is in high demand to develop and validate new computer codes. While not reducing the overall demand for wind tunnels, this CFD/wind tunnel partnership produces more effective final designs.

NASA's aeronautical facilities are truly a national asset for aeronautical research and aircraft development. The Unitary Plan Act approved by the Congress made specific NASA facilities available to the DOD and industry to encourage the advancement of aeronautics as a national priority. Over the years, we have had a strong viable working relationship with the DOD across the broad front. The DOD supports NASA in its launch operations and range support and provides a stream of test aircraft articles to NASA which is an invaluable resource to the NASA aeronautical effort. This quid pro quo arrangement has worked very well for both parties. It is important that NASA maintain management control of these national facilities for the best interest of the country. They are used for NASA-specific aeronautical research, cooperative NASA/DOD research, and DOD/industry support for aircraft development. We will continue to work closely with the DOD and continue to give adequate consideration to their priorities in the allocation of facility time an resources. However, we believe that enhancement and modernization of the NASA aeronautical facilities should remain the sole responsibility of NASA.

Question 10: Can the NAS, the new simulator, accurately predict actual flows, shock waves, interaction between forces on an aircraft in different angles of attack? Isn't that another major reason why the investment must be made in facilities in order to produce the next generation aircraft?

Answer 10: Computational simulations of actual flows have been possible for well over a decade; however, only a restricted set of conditions could be modeled with the previous state-of-the-art in computers and computational algorithms. Computational fluid dynamics has produced simulations of shock waves, and shock-boundary layer interactions, as well as aircraft forces and moments for various angles of attack since the early 1970's. These early simulations were accurate predictions for steady viscous flows over very simple geometries and for subsonic and transonic flows over aircraft in conditions where viscous effects are not of primary importance.

The impact of the NAS capability is that we can now begin to attack many complex problems which were heretofore impossible because of computer limitations. Examples of complex, unresolved problems include transition to turbulence, unsteady three-dimensional viscous flow over aircraft, airframe/propulsion integration, and hypersonic flow (which includes real gas chemistry effects).

But even though the new NAS system represents a significant advance in supercomputing, NAS and CFD are not a complete solution. The NAS capability is being used to complement the usage of wind tunnels. Wind tunnel testing is still a necessary part of designing aircraft, but is now used for optimizing configurations rather than conducting parametric tests. While not reducing the overall demand for wind tunnels, this CFD/wind tunnel partnership produces more effective final designs. Our computational capability has become an equal partner with wind tunnel testing and flight testing in the triad of aircraft design technologies.

Question 11a: Are you participating in the Solid Rocket Motor recovery program by using your facilities and your personnel/expertise to assist in this effort by subjecting the booster and attachments to actual flight conditions?

b. If so, does any of the SRM anomaly resolution funding come into your programs, and how much?

Answer 11a: Langley Research Center has analyzed the original and redesigned joint, the aft-skirt and the SRM lower attachment to the External Tank. Langley has also developed the current standard test procedure for selecting O-ring materials.

b. Langley Research Center received from Marshall Space Flight Center $217 thousand for aft-skirt analyses.

Question 12: Is it correct to assume that the next major step in airline transportation will be the expansion of supersonic transports larger and more fuel efficient than the Concorde? I understand from your testimony, that the industry has begun studies of the market, what, exactly, is NASA doing in this area?

a. How much is NASA spending on research and development of Supersonic Transport designs and technology?

b. Shouldn't NASA be a driving force in this technology development?

c. What is going to follow the Concorde in the marketplace, or will SST travel simply die out once the existing aircraft exhaust their service life? Is the United States going to be ready to enter that market, if so, what are we doing, specifically, to assist industry in this effort?

Answer 12: At this point it is premature to assume that the next major step in airline transportation will definitely be advanced supersonic transports. In order to examine this possibility, however, NASA initiated the high-speed civil transportation studies with the industry late last year. These contracted efforts with Boeing and Douglas are examining the potential market for new high-speed civil transport aircraft, the cruise speed tradeoffs, and the technology requirements. The results of the studies will be used to guide our research in this area and determine the pace of these efforts. In the meantime, we plan to continue to increase NASA's efforts on some of the key technologies that are applicable to a broad range of high-speed aircraft.

The FY 1988 NASA aeronautics program includes several fundamental, but key technology efforts that are applicable to future supersonic transport aircraft. The funding for these efforts is $13 million in FY 1988. These efforts include supersonic computational fluid dynamics and laminar flow, supersonic through-flow fans, airframe materials and structures, and high temperature engine materials. There is also some synergism of research in these technologies with other efforts in the National Aero-Space Plane program.

The high-speed civil transport studies could lead to an aggressive government/industry R&T program to develop the required technologies if the studies indicate the potential for viable economics (competitive economic performance with competitve earnings capability and operating costs compared to long-range subsonic transport aircraft) and confidence that the environmental concerns (airport noise, sonic boom, and the upper atmosphere ozone impact) can be resolved. It is appropriate that NASA would be the driving force in this technology development. NASA is working with the industry to define the technology efforts that should be pursued and, based on the results of these efforts, will prepare a proposed technology program to develop and validate the technology in a timely manner to support future U.S. industry aircraft development decisions.

Question 13: Dr. Colladay, what is the status of the IR&D program, isn't it correct that the government's share of the research pie is declining and the industry share is increasing?

What are the relative figures in terms of the shares of each for this type of research, say for any 1985/1986/1987...what is the trend?

Answer 13: IR&D program funds expended by contractors over the last three years for which we have data available rose from $4.0 billion in FY 1983 to $5.0 billion in FY 1984 to $5.2 billion in FY

1985. The ceilings on recovery of these funds that were accepted by the government as allocable to all contractor business progressed from $3.0 billion to $3.9 billion to $3.5 billion over these years. The DOD share of the accepted costs progressed from $1.6 billion to $1.9 billion to $1.0 billion. The NASA share of the accepted costs progressed from $78 million to $86 million to $90 million. The government-accepted ceilings for FY 1986 and proposed for FY 1987 through FY 1989 remain constant at about the FY 1985 level with a 3.5 percent annual percent for inflationary increase.

Question 14a: Dr. Colladay, in light of the fact that NASA's research and technology base has been seriously eroded over the years, why did NASA only initiate a five-year program when it had the chance, and what was the rationale by which the six key technology areas were identified (propulsion, automation and robotics, vehicles, information, large structures, and power for inclusion in the program)?

b. What are the primary goals and objectives of the program, and are these to be met in five years?

c. Is it your intention to augment this program in the outyears with other key technologies?

d. Does NASA intend to use this initiative as a recruiting mechanism to attract the next generation of space scientists and engineers? To what extent will these activities be conducted in-house?

Answer 14a: As a first step in restoring the nation's space technology base, CSTI was established to achieve specific technical capabilities as a means of strengthening identified gaps in our space technology program. The program will concentrate on a limited set of technology objectives to support access to and operating in earth orbit and to enable next-generation science missions. CSTI will establish a solid capability basis from which to proceed with a vigorous, longer term R&T program directed at bold missions of the future. It was structured to meet these needs, with peak funding developing within five years. Many of the program elements will continue beyond that five-year period.

Selection of the technology areas for CSTI was based on their relevance to recovery and their support of agency missions. The selected technologies are the very highest priority and in traditional areas of agency leadership.

b. The CSTI objective is to perform focused research and develop specific technologies crucial to providing the technical base with the systems options necessary to ensure a high probability of success for high priority agency and national goals.

As a result of CSTI, we can expect to achieve key technology advances in the areas of Earth-to-orbit transportation, earth orbiting operations, and technologies for science missions. For example, we can expect substantial performance gains in next-generation rocket propulsion vehicles; we will make major gains in resolving the technology for processing space-derived information quickly; we expect to achieve verification of a high-demand nuclear electric power conversion system for space operations; we can expect significant progress in increasing spacecraft payload to geosynchronous orbit; and there will be progress in instrument development for remote sensing.

c. Yes, there is a continuing need to address the goals that relate to missions beyond Earth orbit. These will call for other key technologies, as well as different aspects of CSTI technologies. Furthermore, the needs for improving capabilities for access and operation in Earth orbit will continue to evolve and technologies in outyears that serve this goal will correspondingly emerge.

d. The revitalized Space R&T program and the added CSTI-focused program elements are expected to serve as an attraction for new generations of space scientists and engineers, both at NASA and at the industry and universities where the tasks will be pursued.

Question 15a: In the case of CSTI, isn't it true that the issue of "Humans in Space" was completely excluded from the final package? For example, would you please explain to the Subcommittee what the "Pathfinder Program" was that OMB rejected for inclusion in the FY 1988 budget submission?

b. How can NASA be considering a bold new initiative such as a lunar base or a manned Mars mission if the necessary advanced technology development activities--closed-loop systems and bioregenerative systems--are not being initiated now? Aren't the Soviets and Japanese working on these systems?

Answer 15a: The "Humans in Space" issue was not included in CSTI because it fits more appropriately in the context of Pathfinder. Project Pathfinder is a possible extension of CSTI, building toward a technological capability beyond earth environment. While CSTI is directed at earth orbit technologies, Pathfinder would address critical technologies for missions beyond those that are focused on earth orbit, i.e., the moon, Mars, and the outer planets. Examples of potential Pathfinder technology thrusts are long-duration exposure for humans in space, lunar and asteroid materials processing, interplanetary nuclear electric propulsion and communications, and planetary rovers.

b. It is true that long-duration missions of establishing a lunar base or undertaking a manned Mars mission will require appreciable advances in life support technologies, perhaps including bioregenerative systems. In fact, we have already initiated studies intended to identify new regenerative processes and technologies for closed-loop life support systems. However, life support processes involve both oxygen and water in large quantities. In addition, other critical systems such as fuel cells for electric power and auxiliary propulsion thrustors may be efficiently fueled by hydrogen and oxygen. Therefore, any selection of new life support regenerative processes and technologies for advanced development must be accompanied by an understanding of their potential for integration with other space systems that may share the use of hydrogen and oxygen. We are initiating study activities to examine such integrated systems.

Currently, the Europeans, Japanese, and Soviets are behind the U.S. in the development of regenerative life support systems. The Europeans currently only have development underway in regenerative atmosphere revitalization and are only doing analysis of other advanced systems. The Japanese have an active regenerative life support development program which basically mirrors that of the U.S. and they are trying to catch up. However, they have a very aggressive three-phase space food production plan in place which would begin in 1992 and start initial system demonstration in 1999. The Soviets have basically relied on nonregenerative life support systems, but have extensive flight experimentation in growing plants in space.

Question 16: Recently, the Air Force indicated that it intended to develop a heavy lift launch vehicle (HLV), and toward that end it was going to initiate a technology development program in FY 1987--if a supplemental were to be approved. One of the major elements of the Air Force HLV technology development program was research on the liquid oxygen/hydrocarbon engine.

a. To what extent has NASA discussed CSTI with the Department of Defense, in particular the Air Force? Do the objectives of the NASA and DOD propulsion research programs complement each other or duplicate each other?

b. Do any of the initiatives in the NASA CSTI program support the Aerospace Plane program? How much of the Space Research and Technology Base program is directed toward the Aerospace Plane?

Answer 16a: DOD personnel have been briefed on the entire CSTI initiative, and OAST personnel responsible for the NASA propulsion technology have briefed appropriate DOD personnel on the scope and content of the CSTI propulsion element. This is part of a continuous effort whereby NASA propulsion personnel maintain contact with corresponding DOD space propulsion programs through a continuing series of technology exchange meetings and joint reviews of all contracted technology efforts. Furthermore, an Air Force representative is a member of the Advanced Research and Technology Subcommittee (ARTS) of the NASA Space Systems and Technology Advisory Committee (SSTAC) which annually reviews and provides advice and guidance on the OAST propulsion R&T program.

NASA personnel have an excellent understanding of the Air Force R&T program. Duplication exists only when alternative approaches are appropriate.

b. CSTI does not support the National Aero-Space Plane (NASP) program.

In FY 1987, $4.5 million of the Space R&T Base is directed toward NASP. We expect about the same level of support in FY 1988.

Question 17: It appears from the budget summary that the Research and Technology Base declines about $18 million, from $133.6 million in 1987 to $115.9 million in FY 1988.

a. Is this an actual reduction, or simply a transfer to CSTI? If it is a transfer, how much is transferred, and for what purposes?

Answer 17: It is a transfer to CSTI. The FY 1988 program has been restructured into two parts. The first part is the R&T Base which will retain the generic discipline orientation of the past and provide the seedbed for new ideas and a stronger university program. The second part, which is CSTI, is a redirection of some ongoing programs and includes a substantial augmentation.

In FY 1988, $20.7 million was transferred from the R&T Base program to the CSTI program, leaving the R&T Base at $115.9 million. The funding transferred from the R&T Base will support efforts in propulsion, information systems, large structures and control and power.

Question 18a: Regarding Aero-space Plane, does the CSTI program envision or plan on the NASP as the basic transportation mechanism to low earth orbit in the 2010-2020 timeframe? Where do you see the Aero-space Plane fitting in with respect to the Shuttle II debate, HLV's, ETC?

b. Isn't it doubtful that the Aero-space Plane will ever be a 100,000 pound payload delivery system for the Civilian program.

Answer 18a: If the NASP X-30 experimental vehicle is successfully flown by the mid-1990's, then an operational launch vehicle based on NASP technology might be available as an optional space transportation system after the year 2000. The CSTI program, would consider this option, but does not plan on NASP as the basic transportation mechanism.

As stated, the NASP program is a technology development program for a new class of airbreathing hypersonic aerospace vehicles, and not a program for developing an operational launch vehicle. It should provide an option for the next generation Shuttle. NASP should not be related to nearer term decisions to develop an HLV.

b. It is much too early in the NASP technology program to project potential payload weights. Future studies and analyses based on successful development of the technology will likely define a number of potential civilian and military applications, which will then determine an optimal payload size.

Question 19: Despite the importance attributed to the Administration's efforts to define critical goals and technologies in aeronautics that will maintain U.S. leadership and enhance our competitive posture, industry seems to be concerned with the lack of a coherent implementation plan and a coherent program to eliminate the institutional impediments that restrain the efforts to achieve these goals.

In particular, Dr. Krone in his testimony today points to the level of funding, the area of federal contracting, the philosophy concerning the use and support of govenment wind tunnels, the philosophy concerning internal and international cooperation, and the restrictions on publishing the results of basic research.

a. Would you please comment on these industry concerns and indicate what steps you are taking to correct these impediments to fulfillment of the goals that were established in the 1985 OSTP Report?

b. In light of the importance that is given your statement to the role of the Nation's aeronautics industry as a barometer to U.S. technological leadership and as a critical element in the U.S. balance of trade, why is the aeronautics research and development base program reduced by $1 million in the FY 1988 budget request compared with the FY 1987 budget?

c. Why hasn't the Administration initiated a focused and directed subsonic and supersonic research program to maintain the competitive posture of the U.S. aerospace industry in world markets in the same way they have instituted the Civilian Space Technology Initiative for space and the Aero-Space Plane research and development program for hypersonics?

d. Why hasn't the Administration instituted a major facilities modernization program that will improve the Nation's testing and verification capabilities -- especially a modernization of the 16 NASA wind tunnels? How do existing U.S. facilities compare with those of our primary competitors?

Answer 19a: NASA fully supports the National Aeronautical R&D Goals and the eight-point action plan for achieving the Goals contained in the sequel report entitled "Agenda for Achievement". This coordinated national strategy specifically addresses many of these issues. The report highlights that as a nation, we need to do more--NASA, industry and the university community--to preserve U.S. leadership in the face of intensifying global competition. As was true of the original National Goals report, the recommendations in this latest report will undoubtedly influence NASA's aeronautics planning and future budget formulation. In an area not addressed in the sequel, federal contracting procedures, we have originated the NASA Research Announcement (NRA) to stimulate innovative research and streamline the procurement procedures for research and technology contracts. Instead of a lengthy and detailed statement of work, the NRA allows an abbreviated description of the research area of interest thus enabling the contractors to quickly respond with innovative approaches and ideas that offer high payoff.

b. The aeronautics program was given a 12 percent increase in FY 1987 in a level funded year and if you include the National Aero-Space Plane the increase is 25 percent. The FY 1988 aeronautical budget request is $10 million above the runout of the FY 1987 program. Within the overall budget of the agency and the difficult budget constraints that the country faces, NASA is maintaining a highly-productive program focused on cutting edge technologies.

c. Major NASA investments in subsonic research over the past ten years (approximately $1.0 billion) have matured technology in several areas to the point where industry is now preparing to apply it to new products in the early 1990's. A prime example is the high-speed propeller technology which NASA pioneered has led the way for the industry development of advanced turboprop propulsion systems, including the General Electric Unducted Fan (UDF) engine. NASA is currently focusing its subsonic transport research efforts on replenishing the technology base with emphasis on: automation, safety, composites, and laminar flow control. The laminar flow control efforts are concentrated on conducting flight research with a hybrid laminar flow control (HLFC) gloved section on a large transport aircraft in order to address the remaining technical issues. NASA and the DOD also continue to make major investments in the development of technology for high-speed, highly automated rotorcraft. These investments include the RSRA/X-Wing research vehicle which is currently being prepared for flight testing. In the technology base, the rotorcraft research efforts are focused on reducing noise and vibration. In NASA's subsonic technology program, we will continue to assess the needs for additional major program efforts and factor them into our program plans.

Over the ten year period from 1971 to 1981, NASA invested over $130 million in supersonic research developing an advanced technology base beyond the levels incorporated in the final U.S. SST design. These technology efforts included research on supersonic cruise aerodynamic configurations, variable cycle engines, nozzle noise suppression, materials and structures, and low-speed aerodynamics. The current NASA aeronautics program includes some small $13 million fundamental R&T efforts in key technology areas including supersonic computational fluid dynamics and laminar flow, supersonic through-flow fans, airframe materials and structures, and high temperature engine materials. There is also some synergism of research in these technologies with other efforts on the National Aero-Space Plane program. In addition, NASA has a highly productive research program addressing the technology for advanced fighter aircraft with unprecedented maneuverability and short takeoff and landing capability. In order to define the additional research that should be pursued for future high-speed civil transport aircraft, NASA has recently initiated contracted studies with Boeing and Douglas to assess the potential market, identify the cruise speed tradeoffs, and determine the technologies that are required for an economically viable, environmentally compatible vehicle. These studies could lead to an aggressive government/industry R&T program to develop the required technologies if the studies indicate the potential for viable economics and confidence that the environmental concerns can be resolved.

d. NASA is taking several steps to ensure that its critical national aeronautical facilities are maintained and modernized to meet the increasing demand projected for the new aircraft development programs and improve the Nation's research and verification capabilities. First, within the constraints of existing budgets and manpower, NASA has continued to maintain its facilities and carefully prioritize the investments in new facilities in order to provide capabilities. Second, in order to improve the productivity and quality of the data from these facilities, NASA has allocated additional funds in FY 1988 for upgrading data systems, displays and instrumentation. Third, NASA has embarked on a major national assessment of future wind tunnel utilization requirements and the state/adequacy of existing NASA wind tunnels to meet these requirements. This assessment will form the basis for developing a time-phased, prioritized NASA plan for modernizing, rehabilitating, or removing current tunnels from service and providing new capability.

In most testing regimes, existing U.S. facilities compare very favorably with those in other countries. These facilities include the recently completed National Transonic Facility at NASA's Langley Research Center, which provides unsurpassed Reynolds number simulation capability at transonic speeds, and the 40x80x120-Foot Wind Tunnel at NASA's Ames Research Center, which provides unsurpassed capabilities for testing large models or actual aircraft/helicopters at subsonic speeds. Foreign countries have also recognized the value of facilities for technology leadership and have developed a few wind tunnels with premier capabilities. The DNW subsonic wind tunnel, located in the Netherlands, provides capability for open test section operation in the largest anechoic test chamber in the world.

Aeronautics Program

Question: At what annual level has the Aeronautics R&D program been funded over the last decade as compared to the annual NASA funding? (Display in FY 1988 dollars.)

Answer: The requested information is displayed below in constant 1988 dollars (millions):

Fiscal Year	Total NASA Funding	Aeronautics R&D Funding	Aeronautics R&D as Percent of Total
1978	7830.2	439.4	5.6%
1979	8023.0	464.8	5.8%
1980	8336.7	490.2	5.9%
1981	7919.1	389.2	4.9%
1982	7892.2	347.2	4.4%
1983	8443.0	345.8	4.1%
1984	8451.1	367.6	4.3%
1985	8473.0	384.2	4.5%
1986	8439.5	366.6	4.3%
1987	11029.1	393.7	3.6%*
1988	9481.0	375.0	4.0%

*4.5 percent if $2.1 billlion for orbiter replacement is excluded from NASA total in FY 1987.

Question: At what annual level has the Aeronautics Systems Technology program been funded over the last decade as compared to the Aeronautics R&D funding? Explain the underlying factors resulting in any significant increases or decreases. (Display in FY 1988 dollars. In the comparison, break out separately the funding for the Numerical Aerodynamic Simulator computer operation and the remaining funding for the Systems Technology program.)

Answer: The requested funding information is provided in tabular form below in constant 1988 dollars (millions):

Fiscal Year	Aeronautics R&D	Systems Technology	Numerical Aerodynamic Simulation (NAS)	Systems Technology Without NAS
1978	439.4	250.9	-	250.9
1979	464.8	271.7	-	271.7
1980	490.2	298.1	-	298.1
1981	389.2	197.3	-	197.3
1982	347.2	120.7	-	120.7
1983	345.8	100.7	-	100.7
1984	367.6	101.2	19.8	81.4
1985	384.2	133.6	29.7	103.9
1986	366.6	118.2	30.7	87.5
1987	393.7	107.9	31.4	76.5
1988	375.0	89.8	39.7	50.1

The Systems Technology growth from FY 1978 through FY 1980 primarily reflects the buildup of the Aircraft Energy Efficiency (ACEE) program, which included Energy Efficient Engine, Energy Efficient Transport, Engine Component Improvement, Composite Primary Aircraft Structures, Advanced Turboprop Systems, and Laminar Flow Control.

The subsequent year decline in Systems Technology funding reflects a combination of the logical conclusion of the ACEE program, as well as terminations in Systems Technology activities such as the Variable Cycle Engine, Supersonic Cruise Research, and Advanced Composite Structures programs, and Gramm-Rudman-Hollings impacts in 1986 to the Oblique Wing Technology and Advanced Turboprop Systems programs.

As indicated in the above table, in 1978 the Systems Technology programs were 57 percent of the Aeronautics budget and in 1988, excluding NAS, the Systems Technology programs are 13 percent of the Aeronautics budget.

Excluding NAS, the FY 1988 Systems Technology programs consist of the following activities:

	FY 1988
Systems Technology	50.1
Rotorcraft Systems Technology	5.0
Advanced Rotorcraft Technology	(5.0)
High-Performance Aircraft Systems Technology	14.6
High-Performance Flight Research	(11.0)
Oblique Wing Technology	(3.6)
Advanced Propulsion Systems Technology	30.5
Advanced Turboprop Systems	(18.0)
General Aviation/Commuter Engine Technology	(2.5)
Advanced High-Temperature Engine Materials Technology	(10.0)

Question 3: To enhance the competitive position of the aeronautics industry in the future international civil market, what specific program areas would have the highest payoff for increased investment in focused technology development and validation, and what level of funding would be required?

Answer 3: The recently released report entitled "National Aeronautical R&D Goals, Agenda for Achievement" lays out a national strategy and eight concrete actions for concerted effort and greater achievement by NASA, other federal agencies, industry and the nation's universities. It provides a strong and positive framework for achieving the National Goals and preserving American leadership in the face of greatly intensifying global competition. The report ask NASA to take a more assertive leadership role in developing the fundamental knowledge base in high-payoff emerging areas such as composites and high-temperature materials, advanced propulsion, numerical simulation, auto mation and laminar flow. All of these technologies could have a profound effect on the competitiveness of a broad range of future U.S. civil aircraft. Results flowing from these fundamental efforts must be technically validated to enable designers to rapidly incorporate these new advances into specific products with the necessary degree of confidence in performance, integrity, and certificability. It is high-risk in nature and is the most costly part of the R&T chain because it often involves large-scale hardware.

Individual firms often lack the resources to undertake this costly, high-risk technology development alone.

Long-distance, high-speed transports remain one of the greatest unexploited opportunities for positioning the U.S. for leadership in world civil aviation markets at the turn of the century and beyond. In this regard, NASA recently initiated a high-speed civil transportation study in cooperation with the aeronautics industry to examine the market needs and to identify the economic, environmental, speed, size and fuel characteristics necessary to become a successful element in the international air transportation system. The study will also determine the most attractive technical concepts and the necessary technology developments. We are hopeful that the study will help to establish a National consensus and strategy that would support a U.S. industry initiative in this area.

Such a program must complement and take full advantage of aerospace plane technology for transport aircraft in the high supersonic flight regime. In the meantime, NASA is maintaining a small but growing effort in the critical technologies.

Question: Considering the importance of hypersonic technology applications to future US aeronautical leadership, is there a need for flight validation of any of the fundamental hypersonic technologies in the ongoing R&T base program---or will all hypersonic technology validation needs be met by the National Aero-Space Plane Program?

Answer: There is an important and necessary requirement for carefully selected flight validation experiments for hypersonics technology. In the National Aero-Space Plane Program, we will build the X-30 research vehicle and explore the hypersonics regime above Mach 8, which is the practical limit of ground facilities. Within the NASP Program and the ongoing R&T base, we are currently conducting detailed technical reviews to identify which of the critical technologies require additional flight testing. In all cases, the flight test activities under consideration are either extensions beyond ground test capabilities and computational methods and/or sufficiently complex problems that flight testing is required to provide "real" data. These experiments are both necessary for, and complementary to the NASP program activities.

Because of cost and the long lead time associated with flight testing, we are very rigorous and deliberate in the conduct of the review process. The current review of supersonic/hypersonic boundary layer transition phenomena can serve as an example. The boundary layer transition process has been of continuing interest to the aerodynamics research community for decades. Accurate prediction of "transition" from laminar to turbulent flow at supersonic flight speeds is required in the design process for the NASP vehicle, since it influences both aerodynamic drag prediction and heat transfer rates/heat load to the vehicle structure and cooling system. These data are not available from the Shuttle flight program, nor are they contained in the literature. Currently, university, industry and government specialists are involved in a directed assessment on how best to acquire the necessary data. They are considering a limited, carefully structured, fully coordinated program, which includes a flight research activity. This program will also be reviewed by the scientific community.

QUESTIONS OF SENATOR PRESSLER AND THE ANSWERS THERETO

Question 1: While I recognize that some of the aeronautical research and technology programs, such as the advanced rotorcraft program, are reaching their logical conclusion, I am, nevertheless, puzzled that the total aeronautical research and technology budget request for FY 1988 is actually $1 million less than the FY 1987 appropriation of $376 million. I would have expected that as some programs "ramped down" in funding, newer programs would have "ramped up" in funding to reflect some measure of growth in the aeronautics budget. Can you explain this phenomenon -- is the trend of this budget consistent with the R&D emphasis outlined by the Office of Science and Technology Policy in their "National Aeronautical R&D Goals" report, and the follow-on report, "Agenda for Achievement"?

Answer 1: In order to properly assess the budget trend, there is a need to look over several years. Aeronautics was given priority in the President's FY 1987 budget with a 12 percent increase in an essentially level agency budget. Including funding for the National Aero-Space Plane (NASP), the total program increase was 25 percent. The FY 1988 aeronautics budget request is $10 million above the runout of the FY 1987 program which allows us to move forward in several new areas including high temperature engine materials and major wind tunnel modernization. The Transatmospheric budget reflects planned expansion of high-speed technology development in support of the NASP program.

NASA has an outstanding, highly-productive program focused on cutting edge technologies. Though there has been a lot of progress, there is a need for a more concerted national effort -- by NASA, industry and our universities. As with the original National Goals Report, this latest report, "National Aeronautical and Goals, Agenda for Achievement," will undoubtedly influence NASA's aeronautics planning and future budgets.

Question 2: In my opening statement, I mentioned the growing market share that Airbus and the other European aircraft manufacturers are obtaining in the large commercial transport market. How and to what extent is this trend attributable to a narrowing of our technology margin over these competitors?

Answer 2: While U.S. leadership in the large commercial transport market continues, significant, sustained foreign competition producing economically and technically competitive aircraft now exists. In particular, Airbus Industries has been very successful in penetrating world markets. The narrowing of our technology margin is one of the major factors in this success. The latest addition to their product line, the Airbus A320 aircraft rolled out on February 14, 1987, with more pre-flight orders (437 total) than any other new aircraft in history. The A320 is a state-of-the-art technology aircraft. It includes an advanced flight control system with fly-by-wire and side stick controls, composite vertical and horizontal tails, and an advanced supercritical wing.

There are many other elements in the competitiveness equation, but technology is the a very important factor. In the past, the U.S. dominated the civil transport market with the introduction of advanced technology aircraft like the initial swept-wing jet transports and wide-body turbofan transports. If the U.S. industry offers a product with clearcut superiority -- advanced technology at a lower cost -- the other non-technical factors contributing to a foreign competitive advantage would likely have less effect.

Question 3: In what aeronautical technologies is the United States most competitive vis-a-vis our foreign competitors, and in what aeronautical technologies are we the least competitive or is our technological margin narrowing most rapidly? What specific programs are currently underway or will soon be introduced at NASA to help reaffirm our aeronautical technology superiority?

Answer 3: The United States holds a lead in computers and numerical simulation, composites, laminar flow technology, propulsion, avionics, advanced military aircraft technology, high-speed rotorcraft configurations, hypersonics and aeronautical facilities. The technological margin is narrowing most rapidly in transonic wing design, flight controls, metallic structures, low noise rotorcraft and advanced cockpits.

NASA has a highly productive program focused on emerging technologies which promise major gains in future aircraft capabilities. A few examples are the high-speed turboprop, advanced composite structures, hybrid laminar flow, National Aero-Space Plane, X-Wing, numerical simulation, high-temperature engine materials, advanced military aircraft technology, and the wind tunnel modernization program. To preserve U.S. leadership, NASA must carry the most promising technologies through validation to ensure rapid and effective transitioning to industry for incorporation in superior U.S. products. The supersonic goal remains one of the great opportunities that's yet to be exploited. NASA is conducting a major high-speed air transportation study with the industry to establish a national consensus and strategy before coming forward with the technology program that would support a U.S. industry initiative in this area.

Question 4a: Generally, what have NASA and DOD learned over the past year as a result of other work on the National Aero-Space Plane (NASP) program--how and to what extent has the focus narrowed?

b. What is the funding profile for the completion of the Phase 2 technology development program, and what is the expected cost to develop an experimental flight research vehicle? How many experimental vehicles will be built?

Answer 4a: We are currently in the technology development phase, which will continue until the end of FY 1989. We have made significant technical progress in the areas of propulsion, materials and structures, and aerodynamics. We have five airframe contractors and three propulsion contractors in a conceptual design phase, which will continue to this fall. We also have initiated a focused technology effort, primarily at the NASA Research Centers and other government laboratories, to support the industry effort.

Some examples of things we have accomplished include verification of ramjet and scramjet engine cycle performance in wind tunnel tests, increased understanding in emerging fiber-strengthened metal matrix composites for airframe and engine applications using supercomputer (e.g., NAS Cray 2) to predict NASP performance.

The focus has not narrowed--we have purposely kept the options open during this period to insure that a variety of promising concepts emerge. In the fall, we will down select to no more than three airframe and two propulsion contractors, to proceed with preliminary design and component development. These contractors will participate to the completion of the technology development phase.

b. The planned funding profile contained in the FY 1988 budget request for DOD and NASA combined is as shown below. These funding amounts could change based on current negotiations.

(Dollars in Millions)

FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993	Total
61	172	369	540	845	620	300	140	3047

The planning estimate for the technology development phase (Phase 2) is estimated to be $800-$850 million and is planned to be completed by the end of FY 1989, at which time the decision to develop and flight test the X-30 will be made. The total program cost is estimated at $3.0-$3.5 billion.

Question 5: What will be the standards for success for this program, and what standards must be met in order to proceed with the development of an experimental flight research vehicle? Under what circumstances would a decision be made not to develop an experimental flight research vehicle?

Answer 5: The criteria for success for the National Aero-Space Plane program will be the demonstration of technologies required for vehicles capable of single stage-to-orbit operation, sustained hypersonic cruise, substantial cross range at reentry/landing, and powered subsonic go-around and ferry flights.

Based on an assessment of technology readiness, which will be conducted in late 1989, a decision will be made whether to proceed with the development of an X-30 experimental flight research vehicle. The decision to proceed would be based on the following: (1) confidence in engine system performance based on tunnel tests to Mach 8 and computational internal fluid dynamics predictions to Mach 25; (2) high-temperature, high strength-to-weight materials that could be available in sufficient quantity to build the X-30; and (3) computational fluid dynamics codes validated for predictions over the entire flight regime.

If the assessment shows that additional technical effort is needed, the recommendation would likely be to extend the present Phase 2 in order to provide added assurance of X-30 success and to reduce programmatic risk.

Question 6: To what extent is the development by NASA of a single-stage-to-orbit airbreathing vehicle likely to compete with the development of a next-generation Shuttle or some other rocket-powered manned launch vehicle?

Answer 6: A launch vehicle based on NASP technology might be an option for the next- generation of space transportation system, competing on a level playing field with rocket-powered, vertical launch vehicles. By the time for that decision, the capabilities of both airbreathing and rocket powered systems will be evident from the technologies that have been successfully demonstrated.

Space transportation requirements in the post-Shuttle era are in two major categories: (1) heavy lift and cargo and (2) personnel and/or high priority payloads. An operational aerospace plane, capable of rapid, assured, and lower cost access to space might be able to satisfy the second requirement after the turn of the century.

Question 7: Could you comment on the likely commercial applications that might result from this program, and when would such a vehicle likely be operational? Likewise, when would the introduction of a transatmospheric cruise capability at NASA be most likly to occur?

Answer 7: The most likely first applications of the NASP technologies are projected to be a next-generation space transportation system or a military aircraft. A commercial aircraft, such as a hypersonic (not transatmospheric) cruise transport, is thought to be a longer term application of these advanced technologies, consistent with historical precedent for advanced air transportation systems.

A hypersonic transport, developed to fly at speeds twice as fast, or more, than the Concorde could have large economic potential for long intercontinental stage lengths. At such speeds, the high productivity resulting from reduced trip times could expand the existing civil market and provide an economically competitive design option. Therefore, NASA has initiated studies with industry to evaluate the operational and economic viability and to identify the most promising concepts for advanced technology high-speed transports (supersonic to hypersonic). The technology base developing in the NASP program will be included in the study.

The results of these studies should provide an indication of how such vehicles would fit into the various world commercial aviation markets.

Question 8: Your opening statement refers to the aging of many of NASA's major wind tunnels and the need for rehabilitation and modernization of these facilities. In fact, it is my understanding that NASA presently has some 15 wind tunnels that range in age from 16 to 56 years.

Generally, what is the efficiency of NASA's wind tunnel capabilities, and how and to what extent, if at all, has the age of these wind tunnels compromised NASA's testing capabilities?

Answer 8: As indicated in my testimony, facilities maintenance is a serious concern. The average age of our major facilities is 32 years. Many of our facilities were built in the 1940's and 1950's and aging does affect their integrity (the 30x60-Foot tunnel at LaRC, which is an operational tunnel, was built 57 years ago -- in 1930). Of particular concern are drive motors, fan blades, compressors, model support systems, and cooling towers.

Over the years, we have exerted every effort to keep our facilities in a safe operating condition or shut them down. Because of the competition for highly sought after funding, we have occasionally been forced to defer rehabilitation and modernization on less program-critical facilities until outmoded efficiency or declining integrity has compelled us to place a facility in a standby mode.

I am very concerned about the combination of age and increased demand; that is why I have initiated a major national assessment of future wind tunnel utilization requirements and the state/adequacy of existing NASA wind tunnels to meet these requirements. This assessment will form the basis for developing a time-phased, prioritized NASA plan for providing new capability and modernizing, rehabilitating, or removing current tunnels from service. This study effort will be completed during 1987. NASA has allocated additional funds in FY 1988 for upgrading data systems, displays, and instrumentation to improve the productivity of its major tunnels in order to help accommodate the increasing test demand.

Question 9a: What is the replacement value of NASA's wind tunnels and other aeronautical facilities?

b. I understand that NASA spends about 1 percent of the replacement value of these facilities toward their operations and maintenance, compared to an industry average of about 4 percent to 6 percent.

Assuming my information is correct, why does NASA spend so much less than industry does for operations and maintenance of its aeronautical facilities?

Answer 9a: The estimated replacement value for the major aeronautical facilities is $1.9 billion.

b. We have also looked at this comparison, and it appears that NASA does spend less than what is spent in industry. Over the last ten years, the portion of the Agency Construction of Facilities (CoF) budget invested in the upgrade, not operations and maintenance, of aeronautical facilities has averaged roughly 1 percent of the replacement value of the major aeronautical facilities each year. The CoF budget includes new construction and modification and rehabilitation to existing facilities. If the routine recurring maintenance of the facilities that is funded from the R&D account is included, the total investment on the order of 2 percent of the replacement value each year exclusive of operations.

Our existing aeronautical facilities are a major national asset and responsibility. NASA has embarked on an assessment of future wind tunnel utilization requirements and the state/adequacy of existing NASA wind tunnels to meet these requirements. This assessment will form the basis for developing a time-phased, prioritized NASA plan for providing new capability and modernizing, rehabilitating, or removing current tunnels from service. This study will be conducted by a committee of experienced NASA, DOD, and industry experts.

Question 10a: How large an investment and over what period of time are you anticipating for any wind tunnel rehabilitation or modernization?

b. Since DOD is a significant user of NASA's wind tunnels, will DOD assist in the rehabilitation or modernization of NASA's wind tunnels?

Answer 10a: As indicated earlier, we have initiated a major national facility assessment. The outcome of this effort will have a strong influence on the shape of the facilities budgets over the next five years at the Research Centers. Although the assessment will not be completed until later this year, two specific facilities will definitely be addressed--the 12 Foot Pressure Wind Tunnel (PWT) at the Ames Research Center and the 10x10 at the Lewis Research Center.

b. NASA's aeronautical facilities are truly a national asset for aeronautical research and aircraft development. The Unitary Plan Act approved by the Congress made specific NASA facilities available to the DOD and industry to encourage the advancement of aeronautics as a national priority. Over the years, we have had a strong viable working relationship with the DOD across the broad front. The DOD supports NASA in its launch operations and range support and provides a stream of test aircraft articles to NASA which is an invaluable resource to the NASA aeronautical effort. This quid pro quo arrangement has worked very well for both parties. It is important that NASA maintain management control of these national facilities. They are used for NASA-specific aeronautical research; cooperative NASA/DOD research, and DOD/industry support for aircraft development. Although it is important for us to work closely with the DOD and that they have some say over priorities, we believe that enhancement and modernization of NASA aeronautical facilities should remain the sole responsibility of NASA.

Question 11: According to your statement, NASA will begin flight tests of the Propfan Test Assessment program to complete NASA's Advanced Turboprop Program. What do you expect the test results to prove, and how do you expect this program to benefit the commercial aircraft industry? Against what standards will you measure success in this program?

Answer 11: The propfan flight tests will provide the large-scale data base for structural, aeroelastic and acoustic scaling important to all propeller/airframe installations being considered by industry. This large-scale verification will provide the basis for optimizing designs of propeller blade aerodynamics, aeroelastics and acoustics, whether they are single- or counter-rotation. The flight tests are designed to be configuration independent and heavily instrumented to provide verification information. The tests will complete NASA's large-scale research. However, NASA is planning to continue turboprop research with emphasis on analytical method development for installation aerodynamics, cabin noise and vibration, and counter-rotation source noise.

The data generated during the propfan flight test will provide a unique data base useful for correlating the wind tunnel experimental data base and validating analytical methods developed within the NASA Advanced Turboprop program. It will be considered successful when the data is available to verify these existing methods and provide scaling information for both new analytical methods and future hardware for commercial applications.

Question 12: NASA's ATP program has focused on the single-rotation advanced turboprop concept, while several members of the commercial airframe and engine industry have staked their futures on the counter-rotation concept. Of what use has NASA's program been to those who are pursuing the counter-rotation concept, and have they "leap- frogged" NASA in their development of the counter-rotation concept?

Answer 12: The NASA ATP program has been structured from the outset to develop and verify the fundamental technology base for both single- and counter-rotation high-speed propellers. Early counter-rotation research resulted in recent analytical method development and model testing of both geared and gearless counter-rotation concepts. This initial propeller technology led the way for General Electric and the rest of the industry. The large-scale verification testing of the innovative Unducted Fan concept was the result of a cooperative venture between G.E. and NASA. NASA's current emphasis in analytical method and experimental data base development is on counter-rotation aerodynamics, aeroelastics, and source noise. These efforts will provide the technology base necessary to optimize counter-rotation performance, structures and noise.

Question 13: I understand that in the FY 1987 budget, NASA eliminated approximately $18 million to $20 million of research to solve propfan-related acoustics and vibration problems. Yet, I also understand that you have allocated approximately $2 million to $2.5 million to three airframe manufacturers to work these problems. With such a large discrepancy in what was originally planned for this acoustics and vibration research and what is now budgeted, what gaps will exist in the data base and what questions will be unanswered? Is industry capable of making up the difference, and, if not, how will these technology issues be adequately resolved?

Answer 13: The acoustics related research eliminated from the NASA Advanced Turboprop budget was approximately $12 million for verification of advanced cabin treatment concepts on the NASA propfan flight test vehicle. The advent of the industry flight tests provided the opportunity to work cooperatively to obtain additional acoustic flight data and with configurations very similar to eventual applications. The $2 to $2.5 million to the three airframe manufacturers (total, over a four year period) is aimed at development of advanced airborne and structure borne noise transmission concepts as well as verification using the results generated in the industry flight tests. There is an important and continuing need for acoustics research related to high-speed propellers and this area will be receiving major emphasis in the NASA budget with $14 million per year supporting research and technology program. The requirement for additional acoustics technology development will be reexamined periodically.

Question 14: Once the ATP flight research program is complete, how do you intend to use the Gulfstream II aircraft -- are there other aeronautical research programs for which it could be used?

Answer 14: The Gulfstream II was purchased by Lockheed and leased by NASA instead of a purchase by NASA in a cost saving decision in FY 1986. Thus, if not purchased by NASA before the end of the planned flight tests (approximately March 1988), the aircraft will be refurbished at NASA expense to salable condition for Lockheed. Because of an excellent purchase price negotiated into the flight test contract, OAST had examined the potential further use of the aircraft. We found that additional cabin environment and icing research could make limited use of the aircraft. The Office of Space Flight is also examining possible use of the aircraft.

Question 15: In 1985, the Office of Science and Technology Policy (OSTP) proposed three national aeronautical R&D goals that related to subsonic technologies, supersonic technologies, and hypersonic and transatmospheric technologies. Certainly, the National Aero-Space Plane program is an appropriate response to the hypersonic and transatmospheric R&D goal. And, while NASA obviously is conducting R&D at varying levels of intensity for the subsonic and supersonic regimes, what is NASA, or the Department of Defense, for that matter, doing in these other two regimes that is commensurate to the priority given to them in the OSTP report?

Answer 15: Subsonic Goal: Major NASA investments ($1.0 billion) over the past ten years in the Aircraft Energy Efficiency (ACEE) Program have matured technology to the point where industry is now applying it to new products for the 1990's. A prime example is high-speed propeller technology where initial NASA technology development led the way for the industry development of advanced turboprop propulsion systems, including the General Electric Unducted Fan (UDF) engine. We will continue to assess the needs for additional major program efforts and factor them into our planning.

NASA is currently focusing its subsonic research efforts on replenishing the technology base with emphasis in automation, aviation safety, composites, and laminar flow control. The laminar flow activity is concentrating on flight research of a Hybrid Laminar Flow Control (HLFC) wing glove on a large transport aircraft in order to address the remaining technical issues. NASA and the DoD also continue to make major investments in technology for high-speed, highly automated rotorcraft. These investments include the RSRA/X-Wing research vehicle which is currently being prepared for flight testing. In the technology base, the rotorcraft research efforts are focused on reducing noise and vibration.

Supersonic Goal: Over the ten year period from 1971 to 1981, NASA invested over $130 million in developing an advanced supersonic cruise technology base. These technology efforts included research on aerodynamic configurations, variable cycle engines, nozzle noise suppression, materials and structures, and low-speed aerodynamics. The current NASA supersonic cruise program includes only a small fundamental R&T effort in key technology areas including supersonic computational fluid dynamics and laminar flow, supersonic through-flow fans, airframe materials and structures, and high temperature engine materials. The supersonic goal still remains one of the great opportunities that's yet to be exploited. NASA is conducting a major high-speed air transportation study with the industry to establish a national consensus and strategy before coming forward with the technology program required to support a U.S. industry initiative in this area. In addition, NASA has a highly productive research program addressing the technology for advanced fighter aircraft with unprecedented maneuverability and short takeoff and vertical landing capability.

Question 16: Do you believe that the nation--government, industry, and academia-- are responding appropriately and aggressively to these three national aeronautical R&D goals? If not, how should we improve our response?

Answer 16: The National Aeronautical R&D Goals were established as a challenge to the entire aeronautics community to focus R&D on high payoff technologies that will sustain U.S. leadership into the next century. Though there has been a lot of progress, such as the initiation of the National Aero-Space Plane Program and the maturing of key subsonic technologies, there is a need for a more concerted national effort and greater achievement -- by NASA, other government agencies, industry, and our universities. The National Aeronautical R&D Goals and the recently released sequel "Agenda for Achievement" present a cohesive U.S. strategy and eight concrete actions. This provides a strong framework for American action in responding to the Goals, but it is only a roadmap for leadership and not a guarantee. Collectively, there is much to be done to achieve the Goals and secure lasting U.S. aeronautical leadership.

Question 17: What is the prognosis for the U.S. developing long-distance supersonic cruise capabilities, and under what circumstances should a National program, such as that of the National Aero-Space Plane, be initiated for a supersonic cruise capability?

Answer 17: NASA has initiated a major study with the industry to examine the potential for an advanced high-speed civil transport. The development of an advanced high-speed civil transport will require a national strategy and commitment with strong industry leadership. The results from this study will be very important in defining the technology efforts that should be pursued. Unlike the National Aero-Space Plane (NASP) program, the final technology demonstration and development of a civil transport aircraft would be led by the aeronautics industry. Verification of the critical technologies would be a joint/cooperative effort between the Industry and NASA so that the technology can be related directly to economic viability. It will not be a return to the approach pursued in the previous U.S. SST program, in which the development was heavily funded and managed by the government.

Question 18: The OSTP report, "Agenda for Achievement", states that the technologies critical to achieving a supersonic cruise capability have not been aggressively pursued by the U.S. since the termination in 1971 of the Supersonic Transport program and the conclusion in 1981 of NASA's Supersonic Cruise Research program. When will the U.S. and NASA begin pursuing aggressively these technologies, and when would a decision to develop such a supersonic cruise capability follow? The same OSTP report infers that the development of a supersonic cruise capability will be largely driven by the market. Exactly what market conditions would lead to the development of this capability?

Answer 18: NASA recently initiated a major study with the U.S. industry to examine the market needs for an advanced high-speed civil transport, and identify the economic, environmental speed, size range and fuel characteristics necessary to become a successful element in international air transportation. The study will also determine the most attractive technical concepts and the necessary technology developments. In the meantime, we plan to continue to increase NASA's efforts in the key technologies that are applicable to a broad range of high-speed aircraft.

The market conditions that would lead to the development of new high-speed civil transport aircraft include: continued strong growth in passenger demand for long-distance intercontinental travel, particularly in the Pacific Basin; a high probability for available airline purchasing power; and validated technology developments that indicate the feasibility of developing a new aircraft with viable economics and environmental compatibility.

Question 19: The OSTP report, "Agenda for Achievement" states that technology is currently the weak link in the R&D chain. Moreover, the report states that to alleviate this problem, NASA must strengthen its capabilities and exert stronger leadership in national research efforts. Why is technology validation the "weak link" in the R&D chain, and what can and should be done to strengthen this link? What can NASA do to strengthen its capabilities and exert stronger leadership, particularly with an aeronautical R&D budget that is declining?

Answer 19: Technology validation provides the expanded knowledge necessary for enabling designers to incorporate new advances into specific products with a high degree of confidence in performance, integrity, and certificability. It is high-risk in nature and is the most costly part of the R&T chain because it often involves large-scale hardware. Individual firms lack the resources to undertake this costly, high-risk technology development alone. There is a need to revitalize the country's validation efforts in key emerging areas such as composites, high temperature materials and laminar flow technology to name a few, in order to accelerate the introduction of high-payoff technologies into superior U.S. products. As the need for technology validation activities occurs, NASA will join with DOD and industry to propose joint/cooperative programs to accelerate technology readiness.

Question 20: In my opening statement, I mentioned the decline in funding for NASA's space research and technology budget over the past twenty years.

What has the decline in funding done to our National Space R&T capabilities compared to that of other national space programs?

Answer 20: During the space R&T program build-up in the 1960's and its subsequent funding decline in the 1970's, the United States was the unchallenged leader in space R&T for the free world. During the 1970's and 1980's, other countries and national consortiums have entered the space age with legitimate investments in space R&T. The result is that U.S. leadership has eroded in specific technical areas. The existence of foreign spacecraft flying today, or planned for the future, is clear evidence of the existence of a competitive technology base.

Question 21: I note that the space research and technology base request for FY 1988 is $115.9 million, which represents a decrease of almost $18 million from the FY 1987 appropriation.

How do you account for this decrease -- to what extent, if at all, is this decrease absorbed in the Civil Space Technology Initiative?

Answer 21: In the transition from FY 1987, the Space R&T program has been restructured. A portion of the ongoing FY 1987 R&T Base which is directly applicable to the CSTI elements has been combined with the ongoing FY 1987 Systems Technology programs and enhanced by $70 million in FY 1988 to make up the CSTI program. The remaining $115.9 million R&T Base continues as the more generic portion of our research. It fosters fundamental understanding and new concepts which will emerge in the future as CSTI-like efforts. In summary, the program is restructured with the more focused aspects of the R&T Base program included in CSTI and the remainder continuing in the R&T Base.

Question 22: As I understand, the Civil Space Technology Initiative is scheduled to conclude after five years. If this, in fact, is the case, why is the CSTI not established as an ongoing program to extend beyond five years -- will there not still be a need for such a technology "push" after five years?

Answer 22: As a first step in restoring the Nation's space technology base, CSTI was established to achieve specific technical capabilities as a means of strengthening identified gaps in our space technology program. It was structured to meet these needs, with peak funding developing within five years. Many of the program elements will continue beyond that five year period.

Question 23a: What are NASA's specific goals and objectives in the CSTI program -- what can we expect to achieve as a result of this program?

b. What are you expecting to achieve in the fields of A&R and in autonomous and expert systems, and how would these technologies be used?

Answer 23a: The CSTI objective is to perform focused research and develop specific technologies crucial to providing the technical base with the systems options necessary to ensure a high probability of success for high priority agency and national goals.

As a result of CSTI, we can expect to achieve key technology advances in the areas of earth-to-orbit transportation, earth orbiting operations, and technologies for science missions. For example, we can expect substantial performance gains in next-generation rocket propulsion vehicles; we will make major gains in resolving the technology for processing space-derived information quickly; we expect to achieve verification of a high demand nuclear electric power conversion system for space operations; we can expect significant progress in increasing spacecraft payload to geosynchronous orbit; and there will be progress in instrument development for remote sensing.

b. In automation, we expect to achieve the development of methods for automating prelaunch activities. We also expect to achieve the ability to permit intelligent control of on-orbit shuttle communication systems and control of multiple subsystems, such as the capability for reasoning and recovery from failures.

In robotics, we will verify techniques for a multi-arm, highly autonomous capability for servicing a spacecraft.

Automation and robotics technologies developed in CSTI will be used in both space and ground operations that are most efficiently and safely done with minimal human supervision. Remote assembly, repair and servicing of space vehicles and structures is one example; the automating of electrical and pneumatic subsystems of future space transportation systems is another.

Question 24: How and to what extent will this program address the technologies that may be required for a heavy-lift launch vehicle or a next-generation Shuttle?

Through the CSTI program, does NASA intend to work with the Department of Defense on its heavy-lift launch vehicle program?

Answer 24: NASA and the DOD have jointly developed technology needs as part of the space transportation architecture studies. These needs are based on the architecture for system requirements beyond 1995. The CSTI elements related to transportation were coordinated with the DOD prior to inclusion in the program as high priority technology needs.

Question 25: I am aware that OMB reduced your FY 1988 CSTI request by $20 million and that OMB denied your FY 1988 CSTI request of $55 million for a Pathfinder program.

a. What does the CSTI program lose as a result of the $20 million reduction and the $55 million denial for the Pathfinder program?

b. What is the nature of this Pathfinder program and is it a candidate for a FY 1989 request?

Answer 25a: As a result of the budget reduction, CSTI elements on orbit transfer vehicle propulsion and on small spacecraft nuclear power systems were deleted and the elements on booster technology, information systems, precision reflectors, power and robotics were reduced in scope in the out years.

b. Project Pathfinder is a possible extension of CSTI, building further toward technological capabilities in space to move beyond earth's environment. While CSTI is directed at Earth orbit technologies, Pathfinder would addresses critical technologies for missions beyond those that are focused on Earth orbit, i.e., the Moon, Mars, and the outer planets. Examples of potential Pathfinder technology thrusts are long-duration exposure for humans in space, lunar and asteroid materials processing, interplanetary nuclear electric propulsion and communications, and planetary rovers.

Our current plans are to reintroduce Pathfinder in the future.

Question 26: In 1983, the National Research Council produced a report on NASA'S space R&T programs. One recommendation of the National Research Council was that NASA/DOD cooperation in space R&T should grow and that NASA/DOD cooperation in space R&T programs could serve the technology needs of the military space effort much as NASA'S aeronautical R&T serves the military's aeronautical technology needs.

Will the DOD cooperate with NASA in the CSTI program? To what extent will technology from this program be transferred to DOD and to private industry?

Have NASA and DOD attempted to establish a cooperative relationship in space R&T similar to their aeronautical R&T relationship?

Answer 26: Where common technology needs exist, DOD and NASA have cooperated in the definition of CSTI elements and the program results will support DOD needs. For example, the transportation elements of CSTI are all high priority, as established jointly in the NASA/DOD space transportation architecture studies, and high-capacity power conversion is an outgrowth of the NASA/DOD/DOE SP-100 program. Industry will be directly involved in performing the program. All technology users, NASA, DOD, and industry, will receive the benefits of the results through reports, papers and workshops.

We are continuously taking steps, as indicated above, in achieving an aeronautics-like relationship with the DOD in space-related activities and believe that CSTI coordination will provide further development of that relationship.

Senator **Riegle**. Let me now call to the witness table Dr. Graham. It has been a while since you have been here, but you have certainly been here before in other capacities, and it is a pleasure to have you here now in your new capacity as the President's Science Adviser and as the Director of the Office of Science and Technology Policy.

I am going to ask you today—I am going to make your entire statement a part of the record. I am going to ask you to try to summarize it in about five, six, seven minutes if you can so that we can save the time for questions.

We have got several other Committee meetings going on in the Capitol at the moment and in the Senate Office Building, so we will have Members coming and going and at some point I too must go to another meeting.

But in the course of your comments, I am going to ask you to touch on two things, and so I would like you to bear these in mind because there may be a place in which you can fit them in as you do your opening comments, or you may want to deal with them afterwards.

The first deals with the final recommendations concerning the report of the National Commission on Space. I know these recommendations have been in OSTP for some time now, and I want to know what we are going to be hearing and when we are going to be hearing it so that we have access to those recommendations as part of our own authorization process for this year. So, I would like some reading from you on that.

Secondly, I would like a clear sense as to the role that your office is going to play, or is playing, in the most recent re-estimates of the cost of the space station. I am interested in knowing from what perspective you are examining that, so I want you to shed some light on that if you can and I would like to know who is in charge of that within the shop. But in any event, why don't you proceed with your comments and then we will get into those things and others.

We are pleased to have you here.

STATEMENT OF DR. WILLIAM R. GRAHAM, SCIENCE ADVISER TO THE PRESIDENT AND DIRECTOR OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Dr. **Graham**. Thank you, Senator Riegle.

Let me try to summarize this on the aeronautics program so that we can get to your other questions as well. As Dr. Colladay mentioned, over three years ago a distinguished committee of industry, government and academia was convened to look at the aeronautics program in the U.S., to understand its status and to evaluate the prospects in the program.

Some people had thought, going into the 1980s as was said once or twice before, we had discovered all there was to discover in this area. I believe there was a proposal around the turn of the century to shut down the Patent Office on a similar argument.

This group that was convened to look at the aeronautics program came to about the same conclusion that one would draw in retrospect with the Patent Office; that is, we have hardly begun to discover the marvelous things that lie ahead in aeronautics.

They proposed that we pursue both subsonic, supersonic and hypersonic flight and transport and put forward some very strong and vigorous proposals in that regard. That Committee has now prepared a sequel to their original report to provide a framework for government, industry and the university community to marshal a concerted effort directed at achieving the national aeronautical R&D goals that were described in the first report.

This timely report, which in fact is being released today and which we call internally "Bird Book Two," from the graphics on the cover, represents a cogent example of industry-government teamwork that is addressing the science and technology issues at the heart of the President's competitiveness issue, and in fact took much of its general programmatic and policy guidance from those initiatives and came to a focus in about the same time frame as the President's proposals for this year, for the proposals that he announced in his January 27th, 1987 State of the Union address.

As Dr. Colladay has described, the challenges to U.S. leadership in aeronautics have threatened the pre-eminence of the U.S. in general aviation, commuter aircraft and rotorcraft markets. Furthermore, Airbus is becoming a formidable competitor in the transport market with its advanced technology, A320 and the planned A340 Airbus models.

The Soviet Union's R&D share of their gross national product investment devoted to aeronautics again challenges U.S. technological pre-eminence.

The committee that prepared this report on national aeronautical R&D goals, an Agenda for Achievement, stresses that the U.S. must not underestimate the level of foreign technology, and even more important, foreign will power and resolve to compete for aeronautical markets and to challenge U.S. technological supremacy in military aircraft.

Because of the monumental advances in technology that lie before us, as exemplified by the first study, maintaining our advanced technology edge will challenge the resourcefulness and creativity of all of our sectors, industry, academia, and the federal government.

To be brief, the committee calls for greater cooperation between industry and the federal government, working closely with the university, the academic community, in four areas in particular: to increase investments, and that means all resources including human potential; and innovative research both by industry and by government; to increase the speed with which new technologies reach the marketplace, a very key issue if the U.S. is to maintain its lead; to expand domestic collaboration among industry, academia and the government; and to strengthen the university and the nation's talent base.

These recommendations, again, are among the fundamentals of the President's overall competitiveness initiative. The President's budget for fiscal 1988 continues to reflect an increased national investment in science and technology with an increase of nine percent or $200 million to $285 million over the current fiscal year;

that is, fiscal 1987, in the National Aeronautics and Space Administration's aeronautics research and technology base.

When you look at the budget, on the face of it, it appears that the research and technology base budget is constant. However, there is an accounting change buried in there which obliterates the nine percent increase that is actually in the budget.

That accounting change came about by moving the national aerodynamics simulator system, the large computational facilities in NASA, from the R&T base to the systems technology line item, and when you take account of that change there is in fact a nine percent increase, this in an environment of stringent and austere budget reductions as we all fight to reduce the national deficit.

The government-wide budget request for the National Aerospace Plane program which is a part of this overall activity but brings in the DOD part as well has approximately doubled from 1987 to 1988 to $325 million. The committee urges the private sector in particular to respond to the intensifying global competition by applying more resources to far-sighted R&D activities, to collaborative ventures to exploit revolutionary technologies, potentially beyond the means of any one company, and to apply more private resources to design, develop and manufacture affordable, technologically superior and soundly engineered products.

The government on its behalf looks forward to further investing in long-range and high-risk basic research activities which underlie our overall technical capabilities and certainly our aeronautical strength, and to continue to provide on a cost basis major facilities which serve a number of different sectors of the industry, military and civil, an a multiplicity of companies.

Let me just close by noting two recent endeavors by private citizens, the trip around the world by the Voyager airplane and its crew, a trip which doubled the unrefueled range of aircraft, something that we might have a few years ago through we were approaching the practical limits of, and the great contributions that NASA's basic technology work in every aspect of that airplane provided, and the great ingenuity that Burt Rutan showed in applying those technologies to such a marvelous craft, along with the excellent pilot skills of the two pilots, and then finally the return to America of the America's Cup by Stars and Stripes and its crew.

A great deal of basic science work was applied in the design of Stars and Stripes. I believe a great deal more can be done in the design of aircraft, of boats and of many other things of more immediate commercial application.

I was told by one of the scientists working on the Stars and Stripes that through advanced computational fluid dynamics in particular, they were able to reduce the course time of the Stars and Stripes by something over—let me say several minutes, far more than the time margins by which the sailing boat won most of its races.

So, I believe that research has made a great contribution to that competition as it can to our industrial competition. We are certainly going to have to use all of our talent and keep it focused on winning the high stakes, high tech international competition in industry as in sport that will certainly dominate our future.

That concludes my prepared remarks on our aeronautical program, Mr. Chairman, and I will address your other questions as you wish.

Senator RIEGLE. Very good. Thank you. I will go to those in a second, the ones I posed earlier, but let me ask you, if you add up all of your recommendations in the action plan of your report, both the government and the private parts of that, what is the best estimate of the total cost that we are looking at there?

Dr. GRAHAM. We have not tried to go through it and pick up the industry section and the government, because in the case of the industry the report contains challenges to them to analyze the market, see what the needs are, and develop their programs forward of that.

Senator RIEGLE. So, we do not even have a ballpark number of what we are—I mean, maybe the cost of doing that is beyond what they are going to have.

How about the government's side of it?

Dr. GRAHAM. Well, the cost of doing it to industry should be borne only in proportion to what they think the return is, and that is a decision better left to the private sector than to the government sector, so the report challenges them to go out and look at the opportunities in areas where they can get a substantial net return to their companies and to our country, and we look forward to as large a return as possible within the investment frame that they can afford.

That framework is substantial, as you know. Boeing, for example, booked nearly $20 billion of new business in commercial aircraft last year. So, they have been very productive and very profitable there and we want to see both industry and the government do what it can to sustain that leadership and that capability.

In the government area, as I said we are already undertaking major activities along the lines recommended here, in terms of increasing the productivity of existing facilities such as our wind tunnel facilities and our numerical aerodynamic simulation facilities.

Right now we have got over a $4 billion replacement cost in our wind tunnel facilities that are under NASA's general dominion. We are investing or have historically invested something like two percent a year in improving those facilities which would be, what, $80 million a year.

We would like the return to be in proportion to any increased investment, but as Dr. Colladay mentioned, we are looking to increase the investment in that area and at the same time surveying industry as the report recommends to see what loads, what demands they anticipate coming forward on those facilities.

Senator RIEGLE. It sounds to me, and I have not heard a number yet, but I have heard a couple of numbers but I have not heard a summary number. I get the sense that we are talking about some number of billions of dollars on the government's side alone. Am I right in assuming that?

Dr. GRAHAM. It depends on the time frame that you put together for this. We are in fact investing around—on the order of two-thirds of a billion dollars a year already in our aeronautics R&T base, if you look between DOD and NASA.

I am sure the investment will continue on that order.

Senator **Riegle**. Is that enough? Does that do it? Does that get the job done?

Dr. **Graham**. I think that is a dynamic question. I think that will do a lot, and I think our first obligation to the country is to get every nickel's worth out of that we can do, and if we are squeezing the nickels to the point that they are screaming and we still see opportunities that we think will return to this country, we will come forward and ask you for those, but we are not to that point yet.

Senator **Riegle**. You know, I really admire your skill as a broken field runner. I mean, it reminds me of Hopalong Cassidy or some of the other football players of years past that were just hard to tackle because they were elusive.

Dr. **Graham**. I do not mean to be elusive, Senator.

Senator **Riegle**. And I mean that partly as a compliment.

Dr. **Graham**. Thank you for that part.

Senator **Riegle**. But it seems to me that the easiest thing to do is to put out a very attractive book with a very strong cover, and with a lot of important issues set forth that call for action and so forth, and I am all for that. But I do not want us kidding ourselves or anybody else as to whether or not we are prepared to invest the resources that are necessary to get the job done, and what I do not want is in sense the repeat of what we are seeing even today in another area with the Tower Commission report where we said one thing and we did something else.

I want to make sure that if we are going to set these R&D goals, that we are practical and realistic about making the up-front investments to get it done. I do not want to kid anybody about the fact that we can do it with the ends of our fingertips, or that the private sector can do it without the corresponding full investment by the government that has to go on, especially when I hear other witnesses telling me that—and I see with my own eyes, that other nations have decided to get into these areas themselves.

They are coming forward aggressively, and I think you have got to give us some cost estimates. I think you have got to give us some figures.

I think the book does not mean much if you do not convert it to dollar signs because that is how we get things done, is by making dollar investments. Can you do that for us?

Dr. **Graham**. That is what we are trying to pull together now in these categories, and we will bring that forward as we pick up the items and the cost. But I do not want to minimize the large investment the country is making in this already at the federal level, and the even larger investment that I am told industry is making in the area.

The investment is substantial now, and we very much take to heart your point that we do not dare fall off on this and get behind the foreign competition. That is, in fact, the theme of the second edition of the aeronautical goals.

Senator **Riegle**. So, will we be getting, then, a second book that goes to the cost, or will we get an appendix that really nails this down so we can actually build and finance a blueprint to do this? Will that be forthcoming, and when will we get that?

Dr. GRAHAM. Well, the book came out today and we will put this book against the aeronautical budget and we will come back to you [1] and tell you how well we are covering it. At first look I think we are doing quite well on that, and on the areas where we do not know what the demands are going to be, we are putting an effort, a substantial effort to find out what the demands are going to be and how to meet those.

So, we are working that problem. We have not finished it yet.

Senator RIEGLE. Before calling on Senator Pressler, let me just say I get very—in the era of Gramm-Rudman, serving as I do on the Budget Committee and as many of us do, on this full Committee here, when we start setting goals and we do not hang the price tag on, you know, there is a question of how serious we are.

Now, I can understand that you may have to take this in two steps, but then I want to get the second step and I think we have got to get that on a timely basis, or I think this does not mean much. It may be right, but if we do not have a plan for getting it done in terms of the concrete steps that cost money, then you know, it could be seen as window dressing and I do not want to see us do window dressing.

Dr. GRAHAM. It certainly is not intended as that, and the fact that NASA is already moving out on some of the aspects, as Dr. Colladay described, and on others we are pursuing from the federal government and challenge industry to pursue in this report, I think indicates that we are not putting this out as window dressing.

In fact, this was written by industry in large part, along with government and academic participation. So, this is not a government edict being placed on industry. This is as much their words as it is the government's.

Senator RIEGLE. Senator Pressler.

Senator PRESSLER. Thank you very much, Mr. Chairman, and welcome, Dr. Graham.

May I ask the first question now. You say that you are putting a higher emphasis on aeronautical R&D yet, as I understand it, NASA's fiscal year 1998 aeronautical R&T budget request declines a million dollars from the fiscal year 1987 appropriation.

Is that consistent with a call for a strong NASA aeronautical R&D role?

Dr. GRAHAM. That is a reflection, Senator, of the fact that there are a number of system technology programs which are coming to maturity and being phased out. They are in many cases going over to either industry or to the DOD that would use them, and those are the areas where the decreases are occurring.

The increases are occurring in the research and technology base. That is the nine percent I mentioned.

Senator PRESSLER. The total budget request is down a million, but you say you are reshuffling within that framework?

Dr. GRAHAM. Yes, exactly.

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[1] As of October 8, 1987, the Subcommittee still had not received a cost estimate from the Office of Science and Technology Policy for implementation of the goals contained in the Office's report, "National Aeronautics R&D Goals: An Agenda for Achievement."

Senator **Pressler**. Would you explain this restructuring of the priorities in aeronautical R&D?

Dr. **Graham**. The budget is divided into two broad categories, and then there is a third that is subsumed in the personnel costs for NASA which do not appear broken out by aeronautics, space and so on. The two categories you do see are system technology programs on the one hand and aeronautics research and technology on the other hand.

The systems technology tends to be specific aircraft demonstration programs, propulsion demonstration programs, technology of that type. The research and technology tends to be more fundamental and basic research activity.

The systems technology programs that are underway now are maturing and the funding is decreasing on those. The research and technology base is increasing by nine percent between 1987 and 1988, along with a nine percent offsetting decrease in the system technology programs.

Senator **Pressler**. Let me follow up on that for a minute. Now as new Systems Technologies programs phase out, why are not new Systems Technologies programs phasing in?

Dr. **Graham**. It is a matter of priority, and it was felt that the priority was better placed on the basic research activities in the aeronautics area, leaving to industry further development of the specific systems technologies. The unducted fan is an example of that. That is now a commercial program.

NASA played a key role in initiating that and doing the basic research. It went up through a demonstration capability and now it is in the hands of industry. We are trying to get more of the applications technology to industry and take on more of the basic research in the government.

Senator **Pressler**. Referring to the National Aerospace Plane program, under what circumstances would a decision be made not to proceed with the development of an experimental flight research vehicle upon completion of the ongoing technology development program?

Dr. **Graham**. I think before a decision was made not to continue that program, a very substantial effort would be made in the technology program. If we encountered something that looked like a formidable barrier, in the first instance, I think we would push harder on the basic technology to see if we could overcome it before we would stop.

The only thing I could imagine is some technological barrier that we saw no way around at this point, and we are certainly not in that situation today. The whole area looks like it is one of substantial opportunity.

Senator **Pressler**. Now what types of national security applications are envisioned for a hypersonic/transatmospheric capability that might result from the National Aerospace plane program, and when would such a military vehicle be required and available?

Dr. **Graham**. I think it would be more appropriate if I left the Department of Defense to address their specific requirements as a function of specific time. As you know, realistically the requirements and the capabilities move together and do not become established independent from one another.

In the military area, of course, a long-range reconaissance, there is one area that such a capability could be applied. In the area common to military and civilian programs of lower cost access to space, launch capability is another, and of course long-range rapid transport of national security forces is a third. Those are at least typical of areas where the national security needs would be involved.

Senator **Pressler**. This will be my last question, Mr. Chairman. Now, the OSTP report, "Agenda for Achievement" states that greater attention must be focused on the availability and quality of scientific and engineering manpower.

Exactly what problems do you believe exist in regard to scientific and engineering manpower? I am told that half of our graduate students in engineering are now from abroad. There are some advantages to that, although if they all go home, our own engineering infrastructure will be depleted.

What does the administration plan to do to address these manpower problems?

Dr. **Graham**. There is a basic demographic problem that is facing us over the next decade and a half which has to do with the subsequent cycles of the baby boom which occurred after World War II, in which the number of people in the group normally taken to be of college age will be decreasing by about 25 percent between now and a decade from now. That is the group from which the scientists and engineers for the next generation are drawn.

The people who are going to be in college a decade from now are already born and walking about, and we cannot make any more of them as U.S. citizens. The fact that that number is decreasing means that somehow we need to increase the fraction of college applicants and college entrants who go into science and technology.

We are trying to increase that in a number of ways, in particular by conducting both Federal and cooperative Federal/State/local programs in the elementary and the secondary schools to provide not only more capabilities in science and technology but more interest and more excitement in science and technology to try to get more people to go into that.

The deficit in our scientific manpower in the universities tends to be made up by people from other countries since we have such a high quality educational base in this country, but in the first instance I would like to see a larger fraction of U.S. citizens go into the science and technology areas, and we are trying to work that problem along with cooperation from the National Science Foundation, the Department of Education and other agencies of the government and then very large activity from state and local and, of course, private professional organizations to get what I would call as an engineer the feedstock for our engineering and science programs more strongly motivated and better trained when they move to the university level and beyond.

Senator **Pressler**. Mr. Chairman, that concludes my questions.

I have some additional questions for the record. I am very interested in learning more about any relationship that might exist between your office and the Advanced Research Projects Agency (ARPA) over in the Defense Department. Furthermore, I question whether we do have leadership from the White House in aeronautical R&D. I am somewhat doubtful, based on the budget request and some of the other things I have observed.

In any event, I ask unanimous consent to submit some questions for the record.

Senator GORE [presiding]. Without objection, and I assume you would be willing to respond for the record?

Dr. GRAHAM. By all means.

Senator GORE. Let me add my words of welcome, Dr. Graham. For those who have already heard, it is always a pleasure to have a chance to talk with you.

During my questioning, I would like to focus on the TAV. Others, including Senator Pressler, have asked some questions about it.

I was reading through your report on the national aeronautical R&D goals. First of all, to begin with, the section on the TAV is entitled Supersonics Goal: Long Distance Efficiency and Environmental Compatibility. I looked through the text, and I don't find anything about environmental compatibility. I see a reference to environmental compatibility at reasonable business risk and one other mention of the word "environmental" in a string of commas.

What do you see as potential problems concerning environmental compability with the TAV?

Excuse me. First of all, let me correct myself. When you say supersonics, the TAV section is the next one, and it does not have the title that I read. I apologize for that, but the question is the same one. Do you see any potential environmental problems with the TAV?

Dr. GRAHAM. The emphasis was on the supersonic transport on the assumption that in the foreseeable future there would be the possibility of many more flights of a supersonic transport than of a transatmospheric vehicle, but that is a nearer-term view, not a long-term view, and you raise a very substantial long-term issue.

We always have to be sensitive, of course, to the noise disruption, sonic boom and other type of issues that all supersonic aircraft have the potential to raise.

In addition to that, of course, there is the possibility of these aircraft putting materials in the atmosphere that are not normally found at various altitudes. That was looked at for a U.S. supersonic transport, particularly in terms of the water vapor and also oxides of nitrogen and other combustion products. It was looked at for the Shuttle, which was not an extremely large problem because of the very limited number of flights the Shuttle takes, and it will have to be looked at for the transatmospheric aircraft as well.

One of the most encouraging aspects of the transatmospheric aircraft is that it would almost certainly be a hydrogen-propelled aircraft, and so its primary combustion product would be water, which is a material that is found substantially in the atmosphere in any case, and it is unlikely that its contribution to the water concentrations would be large at any altitude.

Senator GORE. Well, what I am getting at has to do with the ozone depletion problem. I have done a great deal of work on that problem in relation to the greenhouse effect, and you and I have had private conversations about that, and I am still waiting for some response from the White House on a proposal which I have made with respect to these global atmospheric issues which I think are going to be recognized within two or three years as the most significant environmental problems of this century or the next.

We are beginning to get the first data read out from the computer tapes from the emergency expedition to Antarctica last fall during the astral spring, and I have talked with some of the people who are looking at that evidence. I am told by some scientists that there is an extremely significant question posed by the TAV if the current perception of the ozone depletion problem is valid.

I have asked them what is their gut feeling about the final results of this study, whether it will prove to be valid, and they said over 90 percent likelihood that it will be. So I would just urge you to look early on in this TAV program at exactly what that problem is.

Now, moving to the question of cost, you refer in your statement to a great market driven opportunity for supersonics, yet there does not seem to be much visible activity in this area. How do you reconcile the lack of activity with your perception of a great market driven opportunity?

Dr. **Graham**. I think the budget may not reveal all that is going on in that area. First, it is a prospective market activity.

Senator **Gore**. No, I am not talking about budget activity. I am talking about activity in the marketplace. There does not seem to be much going on with respect to supersonics in the marketplace, or maybe I am just not seeing it.

Dr. **Graham**. I sense a growing interest on the part of the aeronautical airframe companies and engine companies in that area, and the fact that this report was prepared under the chairmanship of one of our foremost aircraft designers and had extensive representation from the industry on it I think is another example of their interest in that market.

Nevertheless, it is by no means a confirmed market to this point, and so one of the recommendations is that industry undertake an assessment of the potential market in that area and that NASA, in parallel, undertake an assessment of the requirements the development of such a capability would entail.

Senator **Gore**. All right, my time is up. Thank you very much.

Senator **Riegle** [presiding]. Thank you, Senator Gore.

In order that we have time within the constraints that we have and get to the next witness, I am only going to ask two other things.

The question I pose to you at the outset is, When will the administration issue its final recommendations concerning the report of the National Commission on Space? The clear sense that I have and what I hear from others is that it is stuck in your shop.

Now that may not be a fair perception, but that is the perception that is there, and I am just wondering when we are going to get these because we would like to have them before the authorization process and not after. We are going to mark up here before long.

Dr. **Graham**. Senator, I would be glad to appear before you at your request to go into that subject in more detail. NASA is looking at a number of activities very carefully at this point. We are reviewing what has been put forward, and I would say that we are talking about a period of time in weeks but not months to have a more complete description of policy in that area.

Senator RIEGLE. We hope to report our bill out by May 1, and we would like to have you on the front end and not on the back end. Can you speed things up?

Dr. GRAHAM. I will be prepared at your request, Senator.

Senator RIEGLE. I think it is important. We really want to take into account what your thoughts and recommendations are, but we want to do it on an orderly basis, and we are under great pressure to produce the authorizations on time because we have always had this process of rolling over the budget timetable, and we do not want to do that. So I guess we have to ask you to speed it up so that we can have the value of your thinking here.

Dr. GRAHAM. We will be ready.

Senator RIEGLE. Can you tell me what is going on in your shop with respect to space station reestimates, what part you are playing there and who is in charge of that?

Dr. GRAHAM. The space station program has, as you know, undergone a very thorough and extensive cost review for one particular design. The base line design has been put forward. I have spent a substantial amount of time over the last two weeks in cooperation with other members of the senior White House staff in reviewing that, and I hate to sound like a broken field runner again but I am going to have to tell you up front that that is a subject which is under very intense review right now.

I am coordinating the review of that to bring forward a series of options for the President on that subject. The options have not yet been fully developed but will be, again, in the immediate future as fast as I can possibly do it along with the cooperation of the other members of the senior staff, in particular, of course, OMB and the National Security Council.

Senator RIEGLE. Do I understand you to say, then, that you are in charge of this? You are the one that is running this review yourself?

Dr. GRAHAM. Neither OMB nor the National Security Council work for me, but I am coordinating the review inside the White House staff, yes, sir.

Senator RIEGLE. Okay, so you are really the man in charge; is that correct?

Dr. GRAHAM. I would say that I am the man——

Senator RIEGLE. In charge of the review.

Dr. GRAHAM [continuing]. Who is pulling the review together and making it happen, yes, sir.

Senator RIEGLE. Can you tell us, how far along are you now, would you say?

Dr. GRAHAM. I had my most recent meeting with NASA this morning at some length, and I believe I and the other members of the staff now understand what they have done or what they have brought forward. They are providing additional material on that on a very quick turnaround basis.

Beyond that, I think we have to look across the options that they have considered and possibly other options that need to be considered to give the President a set of real choices as to how to proceed on the space station, and that full set of options has not yet been developed but is a number one priority on this project.

Senator Riegle. Can we expect to hear from you in the same time frame so that we are ahead of the authorization process here in a matter of weeks, presumably, three or four weeks?

Dr. Graham. In the final analysis, it will be the President's decision as to how to proceed, and I cannot predict or mandate his schedule, but I know he is very interested in the subject, and I would think that time scale would be compatible with it.

Senator Riegle. I assume you would prefer that we have your thinking on this before we go through our markup.

Dr. Graham. Very much so.

Senator Riegle. We feel the same way. I hope we can really move that along as well. I know there are other things going on in the White House these days that are requiring time and attention, but I think it is very important that you nail down what you are going to say to us on the space station: timing, function, cost, the whole thing.

Dr. Graham. Those are exactly the issues we are addressing.

Senator Riegle. Well, just to finish, does it look like we are going to have that within a matter of weeks rather than months?

Dr. Graham. Well, with all deference to the man who finally makes the decision this, which is the President, I certainly hope so. It seems to me compatible with his time scale.

Senator Riegle. Thank you very much.

Senator Pressler has questions for the record, so we will submit those to you. Thank you for your testimony today.

Dr. Graham. Thank you, Mr. Chairman.

[The statement and questions and answers follow:]

Statement of Dr. William R. Graham, Science Adviser to the President, and Director, Office of Science and Technology Policy, Executive Office of the President

Mr. Chairman and members of the committee, it is a pleasure to appear before you today to discuss recommendations for sustaining America's aeronautical leadership into the 21st century.

The Aeronautical Policy Review Committee, a distinguished group of aeronautics experts from industry, government, and academia, has reported to my Office since 1983 on the health of aeronautics. I am sure you are familiar with their 1985 report proposing National Aeronautical R&D Goals to challenge the aeronautics community to focus on aggressive, revolutionary technologies. These goals outlined dramatic technological advances that, if vigorously pursued, could far exceed virtually all of today's civil and military aircraft performance by the turn of the century. These goals have been highly successful in increasing our understanding of what can be achieved. Certainly the Administration and the Congress now have a better sense of research and technology priorities, witness the decision to go forward with the National Aero-Space Plane program.

In 1985, the Committee recognized that success in attaining the goals would depend on a national, collaborative effort to undertake the necessary R&D. The need for such an effort takes on a sense of urgency when we recognize that our global competitors are also very willing to pursue opportunities for their own technological breakthroughs.

The Aeronautical Policy Review Committee has prepared a sequel report to provide a framework for government, industry, and the university community to marshal a concerted effort directed at achieving the National Aeronautical R&D Goals.

This timely report represents a cogent example of industry/government teamwork that is addressing the science and technology issues at the heart of the President's Competitiveness Initiative—A Quest For Excellence—announced in his State of the Union Address on January 27, 1987.

Superior technology has been the trademark of the United States aeronautics industry since World War II. In the field of high-technology products, aeronautics remains a shining star with the largest positive balance of trade among U.S. industries. It is also a major contributor to our national defense, domestic economy, and our mobility. Aircraft incorporate many advanced technologies and stimulate development of a broad range of other high-technology products.

Recent challenges to U.S. leadership in aeronautics have threatened U.S. preeminence in general-aviation, commuter-aircraft, and rotorcraft markets. Airbus is becoming a formidable competitor in the transport market with the advanced technology A320 and the planned A340. The Soviet Union's R&D share of their gross national product investment devoted to aeronautics challenges U.S. technological preeminence.

The Committee stresses that this nation must not underestimate the level of foreign technology and, even more important, their will and resolve to compete for aeronautical markets and to challenge U.S. technological supremacy in military aircraft. Because of the monumental advances in technology that lie before us, as exemplified by the Aeronautical R&D Goals, maintaining our advanced technology edge will challenge the resourcefulness and creativity of industry, of academia, and of the Federal government.

Specifically, the Committee calls for greater cooperation between industry and the Federal government, working closely with the university community to: Increase investments in innovative research both by industry and by government; increase the speed with which new technologies reach the market; expand domestic collaboration among industry, academia and government; and strengthen universities and the Nation's talent base.

These recommendations are among the fundamentals of the President's Competitiveness Initiative.

The President's budget for FY 1988 continues to reflect increased national investments in science and technology with an increase of 9 percent, to $285 million, over the current fiscal year in the National Aeronautics and Space Administration's Aeronautics Research and Technology (R&T) base. The governmentwide budget request for the National Aero-Space Plan program has been approximately doubled to $325M.

To further insure incentives for private investment in R&D, the Administration is seeking regulatory stability for the R&D tax credit.

To increase the transfer of Federal technology, the Administration is proposing a major increase in National Science Foundation (NSF) funding to establish about 15 new university-based interdisciplinary basic science and technology centers in partnership with industry. I will urge that NSF's S&T center concept be extended to other Federal Agencies to further increase the government/industry linkage through partnership with the university community. The opportunity for more direct collaboration between Federal laboratories and industry has been provided by the Technology Transfer Act of 1986. The President will issue an Executive Order soon to facilitate industry access to the Federal science and technology enterprise and to encourage Federal laboratories and individual scientists to seek commercial applications of Federal research. The Administration will seek further changes in our antitrust laws to allow for more domestic industry collaboration to reflect the new international environment of competitiveness.

To further strengthen educational capabilities and expand the base of trained graduates, the Administration has proposed increases, primarily through NSF, in graduate fellowships, scientific equipment investments, and for undergraduate and precollege science and math education.

To encourage U.S. competitive excellence into the 21st century, government research and facilities should provide the "seeds" for innovative technologies. The ingenuity, skill, and drive of the private sector is required to invest private capital in new opportunities to harvest these "seeds".

The Committee urges the private sector to respond to the inteisifying global competition by applying more resources to far-sighted R&D activities, to use collaborative ventures to exploit revolutionary technologies, and to apply more private resources to design, develop, and manufacture affordable, technically superior, soundly engineered products.

The world's aviation system must also continue to expand in safety, capacity, and producitivity. Accelerated use of advanced automation, electronics, and command, control and communications (C^3) technologies is recommended for future aircraft and airspace control systems.

The global population, economy, and technology is shifting farther and farther to East Asia and the Pacific Basin. U.S. access to this vast Pacific area is constrained by travel time of up to 18 hours, resulting in fatigue and lost productivity. Long-distance, high-speed transportation could emerge as a great market-driven opportunity by the turn of the century. The Committee urges the development of the enabling technologies, design, and business foundation for a potential commercial high-speed transport initiative led by industry. The magnitude of such an endeavor may require global participation. To assure U.S. aeronautical supremacy for the 21st century, America must strive to take the lead in the next high-speed transport enterprise.

I wil close by noting two recent endeavors by our private citizens—the trip around the world by "Voyager" and its crew and the return of the America's Cup by "Stars and Stripes" and its crew. Both should serve as models of what can be done when federally supported basic research and resulting technology is harnessed by private citizens and U.S. industries that have their own vision of the future and the inner resources to make that vision a reality.

Just as American scientists, engineers, pilots, and entrepreneurs have competed hard and won these new records and prizes, our industries, government laboratories, universities, and all our talent must stay focused on winning the high stakes, high tech international competition that will certainly dominate our future.

This concludes my prepared statement, Mr. Chairman. I would be happy to respond to your questions.

QUESTIONS OF SENATOR PRESSLER AND THE ANSWERS

Question. Compared to our international competitors, what trends have our national aeronautical R&D achievements followed over the past ten years?

If there has been a decline or a narrowing of our superiority, to what do you attribute this?

Answer. While the United States remains the world leader in aeronautics technology, the gap has closed significantly over the past ten years. The narrowing of our superiority is manifest in the wide variety of foreign aeronautical products which now compete successfully with U.S. products in the international marketplace as well as here in the United States.

This increased competition can in part be attributed to the aggressive position of some foreign industries and their governments in taking advantage of the high market value, high-tech potential of aeronautical products to stimulate trade and to develop high technologies on a broader front. In many cases these products are on a par with U.S. products because of the foreign industries' willingness to incorporate new technologies, many of which have been developed from the U.S. technology base.

Question. The OSTP report, "Agenda for Achievement", states that for the U.S. to compete effectively in the world aviation market, the U.S. aeronautical industry should continue to expand its own investments in R&D.

To what extent *should* the U.S. aeronautical R&D industry expand its R&D investments if we are to be competitive, and what assurances are there that our industry will, in fact, assume this additional responsibility?

Answer. For U.S. companies to remain competitive in the world commercial aircraft market, they must maintain a *decisive* technology advantage over our foreign competitors to nullify potentially favorable government assistance. R&D expenditures are a long-term investment in industry's ability to continue to compete successfully. The amount of additional indsutry investment in R&D will ultimately be determined by the industry and the future market environment.

However, a review of industry incentives, including stabilizing of R&D tax credits, may be required to assure that adequate growth in private R&D funding is being sustained.

Question. The OSTP report, "Agenda for Achievement", states that technology validation is the weak link in the R&D chain, and that NASA must strengthen its capabilities and exert stronger R&D leadership.

Why is technology validation the weak link in the R&D chain, and what can and should be done to strengthen this link? What is the appropriate role for NASA in technology validation? Is this different from its present role?

How can NASA strengthen its capabilities and exert stronger R&D leadership, as the OSTP report requests, with a *declining* Aeronautical R&D budget?

Answer. Technology validation usually involves large-scale hardware testing at a time in the development process when the technical risks are high and financial pay-offs are uncertain. Consequently, individual companies are reluctant to risk the large resources required. NASA has successfully provided this valuable link in the development chain for the aeronautics industry.

NASA's role in planning and management, along with providing its expertise and facilities, has been essential in bringing companies together, usually on a cooperative basis, to verify technology applications. Traditionally, NASA has provided a significant portion of the funding in the formative stages with increased industry cost sharing in the latter stages. Due to the high costs, NASA has scaled back technology validation activities in response to the constrained Federal budget. This has been of particular concern to the industry because of the large number of opportunities that exist now for application of new technologies in the next generation of aircraft.

To strengthen its leadership role, NASA must focus on rebuilding its base of innovative technologies, expert personnel, and unique facilities. These tools combined with innovative approaches for collaboration with industry, such as those afforded by the Federal Technology Transfer Act of 1986, should serve as a magnet of draw more industry resources into joint programs to accelerate technology readiness.

Question. To what extent is the development of a NASA transatmospheric single-stage-to-orbit air breathing vehicle likely to compete with the development at NASA of a next-generation Shuttle or some other manned rocket-powered launch vehicle?

Answer. If the National Aero-Space Plane (NASP) program is successful in demonstrating that air-breathing vehicles can provide access to space, an operational aerospace plane could provide a rapid, low cost successor to the Shuttle by the first decade of the next century. However, many of the technologies being advanced by the NASP program will also advance the capabilities and lower the costs of rocket powered systems. It is premature to rule either system out of the competition at this time. Because of the growing requirements in payload weight, versatility, and access to space, both air-breathing and rocket systems may play complementary roles in our space future.

Question. The OSTP, "Agenda for Achievement," implies that if industry is to develop a high-speed supersonic transport, an international consortium may be required to pool the appropriate amount of resources.

Based on the experience of the joint British/French venture to develop the Concorde, what groundrules should the U.S. establish if we do enter into an international consortium. And under what circumstances would it be in our national interest to enter into an international consortium?

What considerations would argue against an international consortium to develop this supersonic capability?

Answer. The possibility of an economically viable and environmentally compatible high-speed transport, which would cut flying time to the Pacific Rim by 70 to 80 percent, holds significant potential for the world's aviation industry and the traveling public. Such a vehicle could capture a majority of intercontinental markets and represents a multi-billion dollar market for its participants.

The potential gains for the United States in terms of the economy, national security, and technology mandate that we be the leader and have effective control of the resulting program. Japan and European nations are keenly interested and can be expected to expand their R&D investments in this area.

Consideration of an international consortium should be based on the following conditions: A U.S. technology development program which secures U.S. technological superiority; A quid pro quo with other participating nations for sharing of technology; Projected economies that yield seat-mile costs approximately equal to or better than future subsonic aircraft; Infrastructure costs that will be affordable to either government-owned or municipally-owned airports; Resulting aircraft that meet established noise standards and will not degrade the world's environment more than current approaches; and A privately funded aircraft development program without consequential government involvement.

Question. Dr. Colladay's opening statement referred to NASA's aging wind tunnels and the need for rehabilitation and modernization of some of these facilities.

Do you agree with this assessment, and do you believe that a rehabilitation/ modernization program should be a national priority if we are to achieve the three national aeronautical R&D goals identified by the Office of Science and Technology Policy?

Answer. The condition of NASA's aging test facilities is of major concern as increased demand is forecast to meet government and private aerospace development needs during the 1990s. I support Dr. Colladay's decision to initiate a national assessment of wind tunnel use requirements and adequacy of NASA's facilities to respond to this national need. This study should be completed during 1987 and will form the basis for a time-phased plan for modernizing, rehabilitating, and providing new test facilities as well as advanced computation and simulation facilities. NASA has already allocated additional funds in FY 1988 for productivity improvements and is expected to respond favorably to the national assessment with continued increases in future years.

The availability of productive, state-of-the-art wind tunnel facilities is essential to the achievement of the National Aeronautical R&D goals. New test and computational facilities will be required to extend our knowledge base. Facilities that are highly capable and productive will be required to verify expanding computational solutions and to refine vehicle system performance characteristics. Facilities easily accessible to industry will be critical to the development phase of privately funded programs.

Senator **Riegle**. Dr. Krone, let us call you to the table. The Senate has gone in session, and we are under a very tight schedule today. Once you have a chance to get seated, we would like to hear from you the results of the recent AIAA workshop conducted with the purpose of focusing attention and energy on reversing adverse trends in aeronautics.

I know the members of the subcommittee share that concern that U.S. leadership in this area is in some difficulty, and we look forward to your testimony and your thoughts with the hope to correct that situation.

So I am going to make your full statement a matter of the record. I would appreciate your feeling free to summarize and be just as blunt and to the point as you can because this is the time and the place for that.

STATEMENT OF DR. NORRIS J. KRONE, JR., CHAIRMAN, ADVISORY COMMITTEE ON AERONAUTICS, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Dr. **Krone**. Thank you, Mr. Chairman. As a matter of fact, some of the things that I was going to say you said in your opening remarks, and so I will try to make a brief summary of my remarks.

The AIAA is an organization of more than 40,000 engineers and science people spread through industry and government coming essentially from all of the disciplines of the aeronautical sciences, and as such, we are concerned with the trends that we see trends and indications of how we are doing relative to our ability to compete in the international markets in the aeronautical fields.

Relative to making judgments as to whether or not our aeronautical research and development programs are adequate or not, we look at it as, not an absolute value judgment, but one based on relativity. The trends that we see at this time do not look good to us. I will not go through the balance of trade arguments, but I would like to say just one thing about that. Considering the question of aircraft balance of trade, including sales and imports, I think it is significant that the imports are going up and the exports are staying about the same. This indicates that the competitive ability of our adversaries in those markets is significantly increasing. So what we are seeing here is that the trends are in an adverse direction, and we would like to do something about that; and we think there is something that can be done about that. Basically, it is the increase in performance or, in other words, the quality of those future aircraft that can make the difference.

An example of the technology advances that can be attained, cruise missiles in the late 1950s, like the Navajo missile, which was a supersonic missile weighing over 200,000 pounds, could be produced now with current technology for something of the order of 12,000 pounds. So major increases have been made, and they still can be. These possibilities in increased performance have been documented by the NRC and others.

The OSTP goals we support as the long and the short-term aeronautical objectives. A workshop that we had in November had as a primary conclusion and recommendation that the aeronautics program specifically NASA's aeronautics program, is not adequate relative to those national trends. We should strengthen that program in all of the various technology areas.

The NASA budget of $679 million for aeronautics is less than 7 percent of the total. We think that the cause of this low percentage of the total budget is NASA's high priority for maintaining our posture in space, and we certainly do not disagree with that. Under the severe budget constrictions that we see today, however, the total is held fairly rigidly, and therefore the aeronautics programs have to some degree remained at a level we think is inadequate.

Now there is another reason for it, and that is that the sophistication of present aeronautic equipment, aircraft, and what is forecast for the future has gone up by a tremendous amount. For example, the flight control systems in the late 1940s and 1950s were basically simple mechanical systems, a bit of hydraulic and servo mechanisms thrown in, but the flight control systems of the future would be very complex systems of multiplexing architectual equipment as well as many computers, redundancy, millions of lines of software that incorporate artificial intelligence to assist the pilot to cope with the severe flight regime that he is involved with, as well as the high performance of those vehicles.

Now, this is really a double barrel problem we have when we have a time of relatively constant funding of the research programs. In other words, what is needed to advance is a lot more expensive now than it was 20 years ago or 10 years ago.

Senator RIEGLE. Let me just ask you this. Did you get a copy of cost report today?

Dr. KRONE. Yes, sir.

Senator RIEGLE. Did you take a look at it?

Dr. KRONE. Yes, sir.

Senator RIEGLE. What is your sense for what kind of dollar signs or even the range of dollar signs we are going to have to hang on this kind of thinking and the degree in how you might see that as being split between government and the private sector?

Dr. KRONE. Well, obviously that question requires a considerable amount of analysis. I can only speak from the basis of my position in the AIAA with the workshop and so forth. As I see it, we are talking about rather significant increase, for example, in the NASA budget, I would not hestitate to say a 25 percent increase could be easily accommodated in that budget; that should spread across the board of a number of technology areas.

There are three basic goals in that document, that is hypersonic, supersonic and subsonic. Of those I think the hypersonic one is obviously being pursued with vigor by the Aerospace plane program. I agree with previous testimony today that the supersonic area needs a definite boost; as well as and in particular, the commuter aircraft and the rotorcraft low disk loading type vehicles in the subsonic regime.

Just finishing up for a second on the statement, I will not belabor the NASA facilities and the wind tunnel question, but I think it is extremely important that the capabilities of those wind tunnels, including the refurbishment and the rebuilding and building of additional facilities be accomplished as part of meeting those goals. Maybe that would be the first step that should be taken.

The experimental airplane area is another whole area of consideration. We have kind of fallen back in doing that sort of thing recently because of the high cost, which also goes right along with the high cost of each individual technology.

In conclusion, our position is that there is one very large potential market during the next ten years in aeronautics products, aircraft worldwide. Over $500 billion has been estimated. The $375 million that is currently in the NASA R&D section of the aeronautics budget, we do not think is a sufficient enough investment to meet that challenge and to give us the products that will enable us to capture the percentage of the market we would like to capture.

Senator RIEGLE. Very good. I appreciate that, and I appreciate your full statement. You have made a number of points in the full statement that go beyond the summary which will be very helpful to us.

When you look around the world right now, what other nations ought we to be the most concerned about with respect to the gains and the surge that they are making in the aeronautics markets?

Dr. KRONE. Well, the consortium in Europe obviously is one, with Airbus and the demonstrated military technology that they have shown with the Tornado which is several years old—so we can assume that they have advanced in that area. Obviously our prime adversary, the Russians, are making advances also in the military arena.

Relative to the other countries like Brazil, and the Canadians with their commuter successes and even, as mentioned, the Indonesians, which I was aware of five years ago had started a major effort in the aeronautics area, these are all competitors.

I will make one comment, and that is from personal experience. We have an extremely enthusiastic aeronautic industry, and I think that some of the institutional improvements that I have suggested in the written testimony, if these actions can be taken—which are not dollar actions—they are simply in the form of rules, regulations and possibly laws that can be passed giving more encouragement and incentives to this industry—then this will go a long way towards accomplishing the goals that are stated in the Dr. Graham DSTP book.

Senator RIEGLE. You mention in your statement the MIG-31 as being superior. Can you elaborate on that a little bit?

Dr. KRONE. Obviously that is a classified area, and I hesitated to put that in there. I said there that it was reported to be superior, and that is really all it is, is a report, and it is not meant to be an absolute statement. It simply is an indication. It is one of those trends that we see. It is a newer airplane than our current fighter aircraft. It is much newer than the F-15, F-16 or F-14. So, consequently, we would expect it to have better performance or at least a comparable performance.

The point there is that from the standpoint of national security we depend upon an advantage, a superiority of performance advantage over the Communist countries, and this is an indicator that our advantage is being eroded, and that is what it is.

Senator **Riegle**. Let me ask you about wind tunnels and related facilities. How serious is that problem in your view?

Dr. **Krone**. Well, in my view it is a serious problem for this reason. The computational aerodynamics area is one that has been coming along and rightfully. I think it is extremely prudent that we spend the resources to get those capabilities.

Now, from the engineering side of it for a second. Fluid flow considering viscosity, considering shock waves, considering boundary layers (the various types of boundary layers that are involved) over a large number of Mach numbers, under many different flight conditions with different shapes of vehicles, is one extremely complex field and one that we are making tremendous gains in; however, we must consider the fact that they are not perfect.

Now, if we are talking about designing advanced vehicles with the high performance levels, and that goes for supersonic as well as the hypersonic area, I do not think it is realistic to think of designing those vehicles based only on those analytical methods.

What that means is that we have to verify the methods, and you need wind tunnels, and sometimes wind tunnels will not even do it. Sometimes you have to go to the X type flight vehicles, especially when you are talking about integrating numerous different technologies.

So what we are really saying there is that the NASA facilities are excellent facilities, and so are those of the Air Force, and we are in the lead by a substantial margin at the present time in aeronautics and I think to a large degree, because of those facilities.

I think, again, the budget squeeze on NASA is holding down the use of those facilities and also holding down the rebuilding and refurbishing of those facilities. This, as I say, in my opinion and the opinion of our workshop also, is an area where if we were going to spend additional money, as an investment, it should be one of our first priorities.

Senator **Riegle**. I thank you very much. I have a number of other questions. The pressures of other events that we have to deal with today on the Senate floor and elsewhere require us to finish our proceeding here at this time, but I am going to give you those questions.

I want to thank you for the very fine prepared statement that you gave us. I found it to be very helpful, and I think it will help us in guiding some of the decisions of the subcommittee.

Dr. **Krone**. Thank you very much. We will be pleased to be of any further assistance.

Senator **Riegle**. Well, we will be calling on you.

[The statement follows:]

STATEMENT OF DR. NORRIS J. KRONE, CHAIRMAN, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS ADVISORY COMMITTEE ON NATIONAL AERONAUTICS

THE STATUS OF NATIONAL AERONAUTICS

The American Institute of Aeronautics and Astronautics is a professional technical institute with over 40,000 members working through the country's industries, universities, and numerous government agencies. As a technical organization we are naturally oriented towards the future capabilities of our aerospace products which have as their foundation the current technology development activities. The competitiveness of tomorrow's commercial products in world markets and the superiority of the future military aircraft are directly related to the level of support given to "today's" aeronautical technology efforts.

Consequently, we are very aware of trends that provide us with indicators of how well we are doing in the technology race (and it is a race) relative to the rest of the world. These trends and indications can then be used to judge the adequacy of our current technology programs. This judgment is directly dependent upon an evaluation of the strength of the competion and the opportunities for improvement.

Our message today can be characterized by one word—concern. The concern is that relative to the competitions, the trend of our worldwide leadership in aeronautics is in a downward direction and it has a downward slope of significant magnitude. There are clear indicators that support this position. For example, aeronautical products have been a very bright spot in the dismal balance of trade picture for a number of years but the brightness is fading. In 1986 the balance was approximately 10.9 billion in our favor; however, it represented a 14% drop from the previous year. The drop was not caused by a reduction of our aircraft exports (actually increased by about 3%) but by a huge increase in imports which went from approximately $4.5 billion in 1985 to $6.1 billion in 1986.

Likewise, indicators of our military aeronautics position are found in comparisons of the relative performance of our aircraft to foreign designs. Here again the trends are downward. The Russian MIG-31 Foxhound is reported to be superior to any existing U.S. fighter aircraft.

With these and other similar indications, it is our position that the country's current aeronautical technology development programs are not adequate. The question then becomes, is there an opportunity to reverse the situation and create a positive trend in our worldwide position in aeronautics? We believe the answer to this question is a definite yes. This belief is based on the potential large gains in aircraft performance that are possible through the integration of advancements in a number of technology areas. These have been highlighted in recent reports such as one by the National Research Foundation.[1] Also, national goals have been established and documented by the President's Office of Science and Technology Policy (OSTP). Despite the significant importance of defining these critical technologies and goals, however there remains a need to define meaningful activities for implementing them and for eliminating the institutional impediments that restrain the efforts to achieve the goals.

The AIAA conducted an aeronautical workshop in late 1986 for the purpose of focusing attention and energy on reversing the adverse trend in aeronautics by focusing support on specific implementation actions. The most important of the recommendations calls for increased funding investments in support of specific technology programs that can lead to superior aircraft performance (both military and commercial) and increase future sales. In recent years foreign governments have been furnishing more and more direct support to their aircraft industry. This includes direct funding for specific aircraft development as well as for technology development programs. In addition, these governments either own the industry or support consolidation practices that would violate current anti-trust statutes in the U.S. We must increase our funding levels accordingly.

Also, there are a number of important institutional impediments that should be eliminated or reduced in severity in order to assure our continued position of worldwide leadership in aeronautics. These include the entire area of federal contracting which should be amended to address the special circumstances surrounding the "buying" of technology; the philosophy which governs the use and support of government wind tunnels and other facilities (and limits their use), the restriction on publishing the results of basic research data, the philosophy that governs the incentives for strong government and industry interaction with research in the nation's colleges and universities; and the philosophy and rules concerning internal and international cooperation.

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[1] *"Aeronautics Techology Possibilities for 2000: Report of a Workshop,"* Aeronautics and Space Engineering Board Commission on Engineering and Technical Systems, National Research Council, National Academy Press, Washington, DC 1984.

NASA FY88 AERONAUTICS PROGRAM

General level

The FY88 NASA budget allocated for aeronautics is insufficient to conduct an adequate aeronautics program. This judgment is based on our assessment of an overall level required to maintain U.S. world leadership in aeronautics. Of the total $10.6 billion requested for NASA in FY88, $679.0 million (less than 7%) is allocated for aeronautics and of this only $375.0 million is for Research and Development activities.

The reason for the low aeronautics R&D level is not due to its lack of importance but rather to the high (and properly so) priority that is attached to the NASA efforts to maintain the U.S. leadership in space. Under the severe restrictions on increases in the total funding level, the aeronautics programs are forced to continue with inadequate funding.

We believe NASA does a good job of managing the available resources and that they understand the areas of deficiency; however, they are faced with an enormous unsolvable problem under the current funding level. Simply stated, they have too many critically important technical areas to cover and are spread alarmingly thin in each area. As the technology becomes more and more sophisticated, the hardware and software becomes more complex, and the resources needed to make advances increases proportionately. This is true in all of the technology disciplines that make up the aeronautical "technology base." As an example, the flight controls of aircraft in the late 40s and 50s consisted of little more than mechanical systems of cranks, pulleys, springs, wire, and simple force and feel mechanisms that connected the pilot controls to the control surfaces. In sharp contrast, the control system requirements of the next generation aircraft dictate a "mind boggling" level of complexity involving sophisticated multiplexing architectures, numerous redundant computers, and millions of lines of software that include artificial intelligence capabilities to assist the crew in coping with the severe flight environment and high performance requirement of these vehicles. In addition, all aspects of the craft's operation (such as flight control and propulsion systems) must be integrated to work harmoniously together. A similar situation exists for the other disciplines that the NASA R&D program is attempting to cover.

To further complicate this situation, NASA is supporting several large flight demonstration programs such as the X-Wing, the X-29, the advanced turboprop (ATP), and others. We firmly support these activities; however, they have likewise become more complex and expensive which puts an even further strain on the aeronautics budget.

The major point we are making is that in real terms the NASA aeronautics R&D program is being significantly reduced by virtue of maintaining a fairly constant funding level year after year.

Office of Science and Technology Policy Goals

We have reviewed the OSTP aeronautical goals and see the transatmospheric (hypersonic) goal as being pursued with vigor in the form of the National Aerospace Plan program. We strongly support this effort as one that promises great benefits for vehicles in the 21st century, and of equal importance, one that will yield high technology spin-offs in the nearer term. NASA deserves much credit for pursuing, during the 1975 to 1985 time period, the technologies and particularly the scramjet and hydrogen fuel efforts that make this program possible.

The subsonic and supersonic goals are suffering under the present budget constraints. The subsonic aircraft systems are in need of emphasis in the areas of commuter and low disk loading (rotory wing) vehicles, and general improvements in light weight, efficient, small propulsion systems. Substantial work is needed to integrate the most current technologies in the areas of handling and ride qualities, acoustic noise reduction, and vibration reduction. Vehicle design concept trade-off efforts that integrate these and the other basic technical disciplines are areas that NASA should assume a greater leadership role. These efforts can have the effect of significantly decreasing cost and increasing sales of commercial aircraft.

Additional supersonic cruise work is recommended to prepare for an advanced supersonic transport and more efficient supersonic military aircraft. NASA should take the lead in performing integration trade-offs and design studies involving handling/ride qualities, propulsion concepts, acoustic control, integrated engine/flight control, natural laminar flow, safety, and other basic concepts that can reduce the dollar cost and increase the viability of an advance supersonic transport. There does exist a high potential market for this type aircraft—specifically on routes between the U.S. to the Pacific basin.

Technology base programs

As a direct result of the low and approximate constant funding levels of spending power for the last five years, all principal areas of the technology base programs are in need of strengthening. We have reviewed the NASA submissions and strongly recommend increased support in these areas: (1) Advanced Materials and Structures. (2) Fluid Flow Prediction and Verification. (3) Controls, Guidance, and Handling Qualities.

Improvements in these aras are important to all classes of vehicles.

Advanced materials and structures.—There is an immense potential for vehicle performance gains through the use of advanced materials in primary structures and in engine hot sections. As an example, the incease in turbine hot section temperature and lighter structures has made possible an order of magnitude reduction in a long-range cruise missile weight, size, and cost over that possible with the technology levels of a decade ago. The NASA program includes a large variety of work on a large number of materials (advanced metallics, ceramics, polymers, carbon-carbon fiber stiffened composites, aluminide matrix-silicon, carbide components, thermoplastic composites, etc.); and in addition, the development of computational structural mechanics methods to analyze and optimize complex aircraft structures. There is much additional effort needed in the areas of material characterization, fatigue, manufacturing and inspection techniques, and cost reduction. Clearly, the potential benefit dictates the advisability of additional funding of this program area.

Fluid flow prediction and verification.—The accurate prediction of flow fields around actual air vehicle exterior configurations or through the propulsion systems—where there exists vortical flow regions, viscous conditions, both laminar and turbulent boundary layers with shock wave actions, a wide variety of mach numbers with unsteady conditions, and under a wide variety of angles of attack—remains an area that requires much effort and large investments. The computational methods are far from perfect. The NASA budget reflects a good appreciation of this situation. However, there remains a shortage of resources to verify the accuracy of the emerging methods and to define their limitations (when they work and when they don't and why). Wind tunnel model and flight testing programs are the principal means for building the necessary confidence in the computational methods and therefore must be expanded by a comprehensive program.

Integrated controls and handling qualities.—The funding for this important area has been reduced by $3.5 million in 1988. This is an example of the squeeze in aeronautics in an important area. In addition to classic control and guidance functions, the control architectures for future aircraft will include the use of artificial intelligence and will function to:

1. Alleviate wind shear and other static and dynamic loading to extend the vehicle's flight envelop.
2. Provide assistance during landing and takeoffs.
3. Optimize the cruise legs through interfaces with ground controllers.
4. Improve safety by failure detection and reconfigurable techniques.
5. Improve cruise efficiency by the integration of the propulsion and flight control surfaces.

NASA research and development facilities

We recommend supplemental funding to support a major upgrade of the NASA wind tunnel facilities. For many years this important area has been underfunded. The NASA facilities that support the country's aeronautics R&D efforts are one of the major elements to maintaining a superior aeronautical posture. There exists a need to refurbish existing facilities in order for them to maintain their efficient usability and to examine areas where technology has moved beyond the capability of the existing facilities. The 16 major NASA tunnels for the most part have been operating for over a generation, and are restricted in their use (the 12 ft. tunnel at Ames is an example). There exist critical shortcoming in the ability to conduct systems research simulation in hypersonic aerodynamics, propulsion and high temperature structures. The cost of upgrading these old facilities and the creation of new ones is so high that a national investment is essential.

Technology demonstration flight programs

We recommend supplemental funding (on a yearly basis) dedicated to supporting technology demonstration programs. Flight research is required for the following reasons:

To demonstrate the integration of a concept or multiple advanced technologies into a flyable vehicle.

To fill the gap created by ground test facilities which do not adquately cover the entire flight regime of future operational vehicles.

To act as a focus for research programs and produce confidence in the advanced technologies.

To accelerate application of high-risk technologies to full-scale operational systems.

To fill the critical gap between laboratory research and system application.

In summary, there is need for a vigorous pursuit of significant experimental and technology demonstrator flight vehicles in order to provide militarily superior aircraft and economical commerical transportation, thereby retaining the pre-eminence of U.S. aeronautics technology.

CONCLUSION

The aeronautics industry is of critical importance to the nation's security and economic well-being. The future health of this industry is directly related to the investment we make in today's aeronautical technology programs. With a projection for over 500 billion dollars in worldwide aircraft sales during the next ten years, it is essential that we make the necessary investments in technology development today. These investments in the past have given us our current position of leadership and they will pay large dividends in the future. Based on this, we strongly recommend a strenghthening of the NASA aeronautics funding in FY88.

Senator **Riegle**. The committee stands in recess.

[Whereupon, at 3:50 p.m. the subcommittee adjourned.]

NASA AUTHORIZATION

THURSDAY, MARCH 5, 1987

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The committee met, pursuant to notice, at 2:04 p.m., in room SR-253, Russell Senate Office Building, Hon. Donald W. Riegle, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR RIEGLE

Senator RIEGLE. The committee will come to order.

Let me welcome everyone in the room today. We have as usual in the early days of the new Congress a number of comitteee meetings that are going on simultaneosly so other members will be coming and going in the course of our hearing this afternoon. We are here to discuss a number of the most important issues that face the U.S. space program. These issues focus primarily upon the recovery programs that both NASA and DOD are conducting after a series of catastrophic failures in both the shuttle and the ELV programs over the last several months.

These recovery efforts are obviously aimed at putting the United States back into space in a safe and timely manner. At the outset, let me welcome you, Secretary Aldridge, and thank you for your appearance before us today on very short notice. I know that was not easy to arrange, and the subcommittee and the full committee are grateful for your help in that respect.

Your insight and testimony have alway been very useful to us, and I know they will be today. You are certainly the most knowledgeable person that we might call upon in the Defense Department, and so we are going to listen with some care to what you have to say to us today.

Our other two witnesses are also very important. Certainly Dale Myers is no stranger to us, and we look forward to his views from the perspective of NASA, and we are also going to be welcoming for the first time Mr. Courtney Stadd, who is in charge of the Department of Transportation's Commercial Space Office.

This committee, as you know, has the responsibility to formulate a fiscal 1988 NASA authorization bill, and that measure must reflect our best estimates of the needs of the agency to carry out its functions. In doing so, we have got to attempt to balance the demands that the shuttle recovery program has placed upon the entire rest of NASA activites from space science initiatives, to the space station program, an effort to maintain our strong emphasis in aeronautics, and other items.

It is in order to meet the judgment of responsibility in that area that we have to determine as carefully as we can where the DOD programs are going, how they will affect NASA's effort, and what the future relationship between the two agencies will be given the mutual need for shuttle capacity and for expendable launch vehicles. Now, the DOD/NASA relationship is a direct and very deep concern to me, and it is a concern shared by an increasing number of colleagues as we try to understand the relationship given the dynamics of budget spending and other operational decisions in recent years. We have just received a GAO report, a copy of which I have here, and there will be copies for the members of the committee and the press that want one—we will make an effort to Xerox these and have enough copies to supply the demand today for those that want it—that addresses this issue.

I had asked the GAO to compare the DOD and NASA space spending efforts over a period of time and they have done so. We are preparing a chart that will reflect the comparative change in growth rates over a period of time, and that is due up here any moment. When it comes, I want to make a reference to it so that we can introduce that into the discussion today, but we have come to a point where DOD is spending over $17 billion a year on space activities, while NASA in real terms is spending a little over $8 billion.

This is something that I think many people have not realized, certainly not in the general public or in the Congress as well.

If you will notice on this chart, starting from the bottom left it depicts years and then going up billions of dollars on the left scale. The upper line starting from the left is the NASA spending line, and you can see how in years past it had gone up to a high level and then came down, and has had sort of an uneven pattern, to say the least. That would be over in the dark area. The lower line would be both NASA spending up to present and the projection out through 1993.

The very sharply rising line is the line that depicts Department of Defense Space Spending, and as you can see that is really taking off like a rocket, if I may say so, but is clearly an exponential curve in terms of growth. Now, the relationship of one to the other is part of what we need to try to understand, both in terms of understanding were there may be duplication or how we avoid the problems of duplication, how we make sure that we are getting our resources spread properly over functions that may overlap between the two agencies. But I think what this chart clearly depicts is the fact that the defense space program is growing at an extraordinary rate, and the NASA program for a variety of reasons has pretty much leveled off and is having an entirely different rate of growth and forecast as we see here in this chart.

So this is one of the things that we will want to talk about today. Other things that this committee is going to have to deal with today are the nature and the structure of the space program and very specifically the space station. I think we have to understand clearly where we are going with respect to the respective relationship on the space station, both NASA as the civilian agency and within the DOD space program, and we want to illuminate that as much as we can today.

Also with respect to expendable launch vehicles, the latest data that I have and if this does not square with the information that you have I would like to have it corrected for the record. The data that I have shows that today in terms of expendable launch vehicles in inventory NASA has 12 remaining, DOD has eight remaining there are two that are in effect jointly owned or under joint control for a total of 22.

In terms of ELVs on order it is a very different pattern. I see 43 on order for the Department of Defense with an option to buy 13 more Deltas and only one ELV on order for NASA, a difference of 43 in the one case, one on the other, so that in terms again of the ELV picture for the future, it would seem to parallel what we are seeing in the way of both these cost curves and these budget projections going forward in time, so I think we have to understand exactly what is being done in that area.

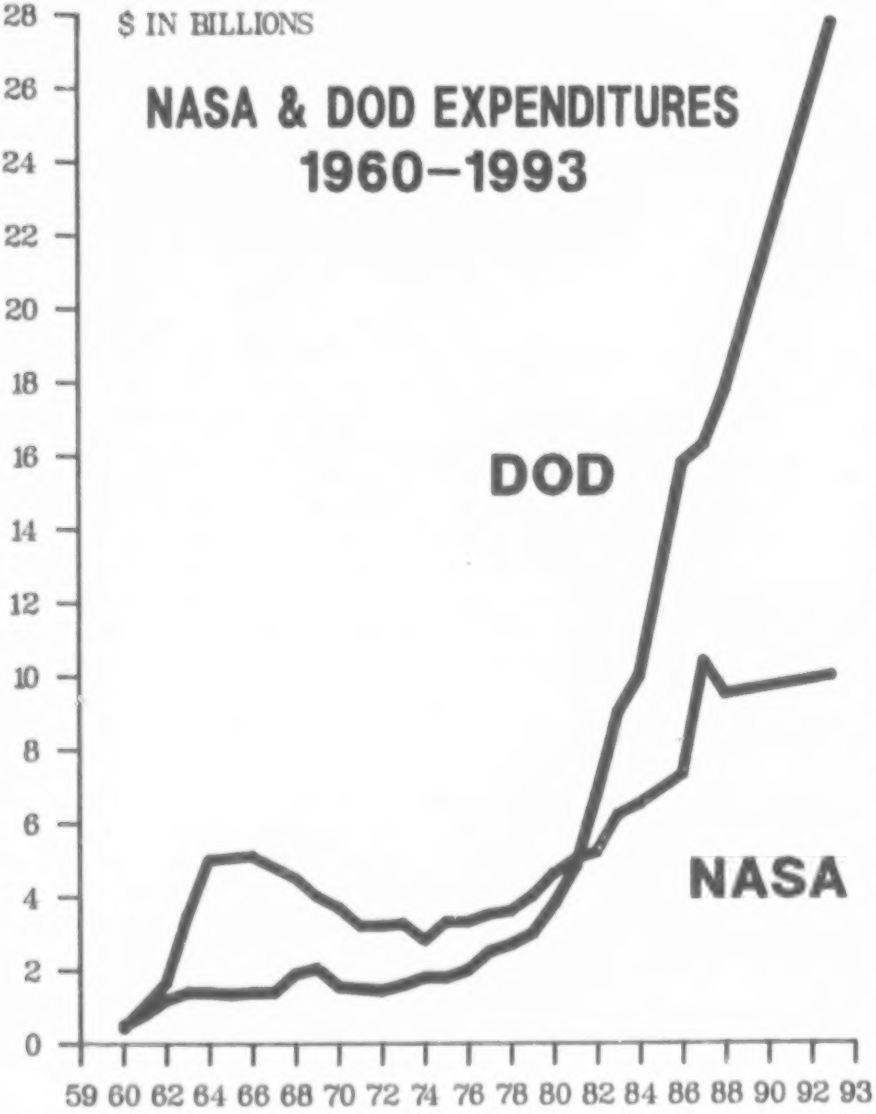
And then finally one other item and that is, when we look at heavy lift vehicle plans there is a concern by colleagues that has been expressed to me, Secretary Aldridge, that if we are going to move ahead now with a heavy lift vehicle that that really is a stalking horse or more than that for the Star Wars program. We really are moving in the direction of in a sense getting that program under way in terms of the ability to deliver large volumes of material into space and the SDI program is really its driving purpose. I would like you to discuss that with us in the course of the day here as to whether or not you see it that way or if you see it differently and how that might be described, because that is also an area of concern.

Finally, I have reintroduced this year with Senator Hollings and other members of the subcommittee legislation that would recreate the National Space Council. And we have done that because we think there is a need to consolidate in the executive branch a policy setting mechanism that is far more effective and focused than the SIG group which most of us feel has failed very badly in recent times.

So we are going to move forward with that effort to try to reestablish that council. Ideally within the executive branch of government the rationalization of any dovetailing of agencies, the civilian space program and the military space program, would conceivably occur within that policy body in the executive branch, within the National Space Council in the future, if that is reestablished, as many of us hope that it will be.

With respect to the Congress, we don't really have a good mechanism for rationalizing these two items, and that is another reason for this hearing today. We are living under the restraints of Gramm-Rudman-Hollings, and necessarily have to try to get our Federal budget deficits down, so we just don't have any extra money to spend, as you both know very well. So figuring out how we allocate scarce resources to two different space operations requires us to know exactly how they fit together and in fact if they fit together, and what the plan is for the future. So that is what we are interested in hearing from you today, and we will get into it in some detail after you have made your statements.

[The chart referred to follows:]



NASA & DOD EXPENDITURES
1960–1993

SOURCE: Office of Management and Budget

Senator RIEGLE. Senator Hollings.

OPENING STATEMENT BY THE CHAIRMAN

The CHAIRMAN. Thank you, Mr. Chairman.

I want to thank you, Mr. Myers, and particularly, you, Mr. Secretary, for being with us this afternoon. What I would like to hear is what you think I ought to hear. Too often I have got a whole deck of questions up here to show you how erudite I am in space but I would like for you to tell me without prompting how we really get ahead. I obviously join in the Chairman's comments, and particularly with respect to the discipline of Gramm-Rudman-Hollings.

We have had a change over on the House side. I never could get Tip to talk about money. Speaker Wright is willing to pay some bills. I am willing to pay some bills. I am preparing a package, and we will have votes for revenues. So as you continue to maintain that discipline, let us do not hold back and tell us four or five years from now that back in 1987 if we had known so and so. I mean you know what we ought to know up here and how we contract with each other on these ELVs and all the other different things.

There's an old adage that the true test of one's character is the ability to overcome adversity. If that's the case, today we will discover the true character of our nation's space transportation program as we explore DOD's and NASA's recovery programs after a disastrous 1986. The loss of the space shuttle Challenger and its crew in January, and the loss of two Titans and one Delta in the 10-month period from August 1985 to May 1986, dealt a devastating blow to the nation's space program. Only the superb performance of our in-orbit satellites has precluded a national security disaster.

Today we are privileged to have before the Committee two of the men who are the architects of the space transportation recovery program—Secretary Aldridge of the Air Force and Mr. Myers of NASA. At the outset, let me thank each of these gentlemen for agreeing on very short notice to testify before the Committee. I am most grateful, and I am sure that the Committee will greatly benefit from today's policy discussion.

As Secretary Aldridge and Mr. Myers know, the Senate Commerce Committee and its members have long had a particular interest in space transportation issues—perhaps it's an outgrowth of the Committee's overall jurisdiction. Whatever the case, it doesn't seem that long ago, Mr. Secretary, when you were secretly campaigning for the Titan II and Titan IV programs because you felt it wasn't prudent for the nation to have a space transportation policy totally reliant upon the man-rated space shuttle. Not everyone wanted to believe you, and you faced a lot of opposition along the way. But thank goodness your views eventually won out, because the adoption of these initiatives prior to the space shuttle disaster has improved our future outlook.

As we look at our space transportation program and the associated policies, it is clear that there are still some very significant policy issues that require our immediate attention. Many of these issues involve NASA and DOD, and those are the primary issues the Committee hopes to explore with you today. However, the Committee also expects to explore some NASA issues that deal with timely and critical matters including the use of ELVs, crew escape systems on the shuttle, preflight readiness firings, and the status of the Second-Sourcing/Bloc II Solid Rocket Motor Report.

I don't think it's any surprise to anyone, but I have not been pleased with the Administration's space policymaking apparatus and the manner in which critical space policy issues have been resolved. Too frequently, the national interest was subjugated to agency interests. Senator Riegle and I tried to correct that last year in the fiscal year 1987 NASA authorization bill. Unfortunately, the bill was vetoed. But we will continue to pursue this initiative until it has been resolved in a manner that protects the interests of the nation.

During the course of today's hearing, I also am hopeful that we will discover from Mr. Stadd that the Department of Transportation's Office of Commercial Space Transportation will really be in the licensing and regulating business this year and that some commercial launches are going to be scheduled. I realize that Mr. Stadd is testifying for the first time before this Committee, so I would like to welcome him. But I also want him to know that the policymaking process for the commercialization of ELVs has been a folly—one of the worst this Committee has ever seen. The fact that a commercial industry may emerge from the failures of 1986 is a miracle—one that nobody can take credit for.

In conclusion, let me say that I look forward to today's candid discussion of the space transportation recovery program and related space policy matters. And, I am optimistic that today's discussion will help the Committee formulate a pragmatic and well focused fiscal year 1988 NASA authorization bill.

Let me just hush and hear from you folks. I want you to tell me what you think I ought to know.

I have a statement from Senator Kerry for the record.

[The statement follows:]

OPENING STATEMENT BY SENATOR KERRY

Mr. Chairman, I welcome this hearing on the National Space Transportation Program and Policy. For more than a quarter of a century, we have made a national commitment to the exploration of space for the benefit of mankind.

As John F. Kennedy said in 1963, "We set sail on this new sea because there is new knowledge to be gained and new rights to be won, and they must be won and used for the progress of all people. . . Whether it will become a force of good or ill depends on us, and only if the United States occupies a position of preeminence can we help decide whether this new ocean will be a sea of peace or a new, terrifying theater of war."

In a sense, Mr. Chairman, we are in danger of following in the footsteps of the Portuguese explorers of the 16th century. They discovered uncharted lands, but left them for the British and Dutch who followed them to develop and profit from their discoveries. Today, we are doing the same thing in space.

By losing sight of our original goals in space, and turning over our space programs to the need of the military, we are forfeiting our lead in space, and abandoning the vision expressed so well by President Kennedy. Space must once again become a "sea of peace", and not a theater of war.

This hearing today on National Space Transportation Program and Policy reflects better than anything we have looked at, the critical flaws in the Administration's space policy, a policy which does not serve out nation well.

The administration decisions and directions set out in NSDD 254 following the Challenger tragedy significantly changed the direction of American space policy. It is time to challenge that change of direction.

The declaration of policy and purpose of 1985 stated, "The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind." We moved forward with science, far space exploration, the Apollo manned mission to the moon and the shuttle. At the same time we developed a new world of communications and technology. If there is a need to divert from the policy which brought us those successes, it should not be in the direction the Administration is taking us. Abandonment of the space agency's commercial launch program and capability makes no sense as the Chairman has noted so articulately on several occasions.

There is no doubt that the valid military national security space needs of this nation must be met. But neither should there be doubt that the valid economic national security space needs of this nation must be met. We must also sustain a vigorous science program which maintains American leadership. We must also build a competitive commercial launch capability if we are to avoid the plight of the Portuguese explorers. We can not maintain our competitive lead or even sustain ourselves as a major player if the development of our capacity is given to the military to meet its perceived national security needs.

What today's testimonies show is that we have turned over control of virtually every aspect of America's space program to the military. Up to 80% of the aeronautics in the space plane are for DoD. A similar proportion of space research and development funding has moved outside of our civilian space program and into DoD. In FY '86 for every $1 appropriated to the NASA budget, nearly $2 went to the military space budget. DoD payloads continue to dominate the Shuttle manifest despite their ELV procurement. Today we note the vast expansion of DoD's launch capability with an increase from 10–23 Titan IV, a new medium range vehicle with 20 rockets and plans to initiate a program for heavy launch vehicles. This is a serious contrast to the NASA budget which has yet to request an ELV capability.

Future programs, from far space exploration to Space Station, are increasingly affected by DoD and disquieting pattern of NASA subservience in decision making is beginning to emerge. The civilian leadership of America's space program and its international championing of openness is at risk today. The loss of that leadership in perception as well as fact is not a welcome reversal.

Throughout the hearings this year we have heard expert after expert testify that they are concerned about the fall off in science, research and development in NASA. We have been impressed with the common concern that without strong commitment to a foward looking and comprehensive space science program we will lose the best young scientists so necessary for commercial leadership and competition.

This nation is in a very real race with the international community. In the Soviet Union, Europe, Japan, China, Indonesia, and Australia, governments are supporting commercial space efforts which present serious threats to our interests. With the Shuttle fleet grounded and the Administration's policy at work we find ourselves shopping in the world community for launch capability. If the administration wishes to move off into "privatization" of launch capability it must be done with a more thoughtful and integrated transition policy.

It is my hope, Mr. Chairman, that today's hearing and the information provided by the GAO report will be of great assistance to this subcommittee in performing the oversight responsibilities which we hold. I commend you for the initatives you have taken to see to it that we are properly focused on these key issues of policy before moving to the very hard budget decisions we must make.

These are very far reaching decisions which set the course across the ocean of space for generations to come. I hope that we have the perspective and wisdom to look beyond single program objectives in both civilian and military agendas and stay focused on the long term future of a balanced, strong and durable American space program.

To that end, Mr. Chairman, I urge that we move forward to passage of the legislation you introduced last month for reestablishment of the National Space Council. It is my hope and expectation that the kind of national and balanced leadership which that structure brought to our previous space policy will be returned to the fore. One must observe that the current administration co-ordination and development of space policy from SIG Space in the White House has fallen short of the vision and urgency so necessary in maintaining the long term space lead this nation deserves.

Senator RIEGLE. Thank you.

I also have a statement that Senator Heflin would like inserted in the record.

[The statement follows:]

OPENING STATEMENT BY SENATOR HEFLIN

Mr. Chairman, let me begin by expressing my appreciation to you and the other members of the subcommittee for giving me the opportunity to once again participate in the activities of this subcommittee, particularly in today's hearing on the nation's space transportation program. Although no longer a member of the Commerce Committee, where I served as ranking member on this subcommittee, I nonetheless maintain a strong interest in programs within its jurisdiction, particularly space transportation. I congratulate the Subcommittee Chairman, Senator Riegle, on taking this initiative.

In the last year, this nation's space transportation capabilities have been dealt a very severe blow. If the tragic explosion of the Space Shuttle Challenger taught us anything at all, it was that we can no longer rely on one method of transportation into space. NASA must develop a complete mixed fleet program. Senator Riegle has shown that he is committed to that goal, and I commend him on his efforts.

Mr. Chairman, It is clear that the nation will need an unmanned launch vehicle in the near-term with lift capabilities equal to or greater than the space shuttle. This, as we all know, is the heavy-lift launch vehicle (HLLV).

Mr. Chairman, before I go any further, let me reiterate that I have always been and will continue to be a strong supporter of Air Force programs and the Air Force in general, particularly its role in the Strategic Defense Initiative. However, I must say that I am extremely disturbed that this Administration has approved an FY '87 supplemental appropriation request by the Defense Department for $250 million for a heavy-lift launch vehicle. The Air Force plans to start with a clean sheet of paper and not utilize existing technology. While I am aware that NASA has been invited to participate in this effort, it appears clear that the intent is for NASA to play a very minimal role. I am concerned that this is a backwards way to approach the development of this vehicle. It simply does not show common sense.

A common sense approach to meeting the nation's near-term and future launch needs would be to build upon, and take full advantage of, the investments that the nation has already made and are still very well in place. These exist in the form of the shuttle propulsion elements, the outstanding test facilities and the teams of people that have gained many years of experience in development of these and other propulsion systems.

As a result of conscious national decisions, launch vehicle development for U.S. needs over the past twenty years had been accomplished by NASA. NASA has shown that they have the foundation and proven expertise in the management and development of propulsion systems. It is my belief that if this nation is to go forward with a joint DOD/NASA heavy-lift launch vehicle program, as this country should, the program should be managed by NASA with the assistance of the Defense Department.

A series of evolutionary steps, starting with the utilization of existing shuttle propulsion elements and assimilating new technologies as they become available, can effectively meet near-term, as well as projected far-term needs of the entire nation, both civilian and military.

NASA programs in several areas would benefit greatly from a shuttle-derived cargo vehicle to complement the space shuttle. The space station could be placed into orbit with fewer launches and, more importantly, with more of the assembly and outfitting done on the ground prior to the launch, rather that after arrival in orbit. Planetary missions are currently very limited by the capability of the shuttle/IUS or the Titan IV. It is my understanding that SDV would nearly double our high-energy launch capability. This capability would also be a large step toward the more important ambitious lunar/planetary missions recommended by the National Commission on Space, and currently under study within NASA. And, as a major consideration, this unmanned vehicle could help quickly recover from the backlog of missions built up from the Challenger accident and subsequent adjustments, and at the same time allow the shuttle to be conserved for those highly important missions that are dependent upon man's presence as part of the flight.

This is an extremely important project for the future of our nation's space program, both military and civilian. Once again, I congratulate Senator Riegle on taking the initiative of this hearing on this matter. And, I am happy to see that he has assembled such a distinguished panel of witnesses, Dale Myers, the Honorable Pete Aldridge, and Courtney Stadd. I look forward to hearing what they have to say on this subject.

Secretary Aldridge, why do you not begin? Before you do, let me just indicate for the benefit of Senator Bentsen, who has just come in, we have just finished our opening statements and we are about to hear from Secretary Aldridge, and if you had any opening thoughts you wanted to express, this would be a good time. Or you may wish to wait.

Senator **Bensten**. Thank you, Mr. Chairman. I would much rather hear theirs.

Senator **Riegle**. Secretary Aldridge.

STATEMENT OF HON. EDWARD C. ALDRIDGE, JR., SECRETARY, DEPARTMENT OF THE AIR FORCE, THE PENTAGON

Secretary ALDRIDGE. Thank you, Mr. Chairman. I have a very short statement this afternoon really addressing the questions that you asked us to address, and of course I would be happy to respond to any questions you may have following my short presentation.

You asked me to address the question of our recovery plan as a result of the Challenger accident and the several failures we had with some expendables. You also asked me to address what we are doing about future launch vehicles, and you also asked me to address what is happening with regard to the DOD/NASA launch vehicle pricing policy. Those were specific questions, although I know there are many more that you would like to respond to.

I was just noticing on that chart I would hope that Congresses of the future will in fact allocate the funding that goes along with that quite rapid rise in DOD spending and certainly that which is associated with NASA. There is one small difference between the two.

I would just like to point out while DOD has research and development in the space program it also has a significant amount of operation and a lot of that cost increases deals with the rapid and necessary growth in the operation and maintenance of space and launch vehicles going along with the operations of space rather than just research and development, which tends to be most of the focus of NASA, so there is a good reason for those differences and maybe we can discuss some of those as we go on today.

First, let me say our recovery plan is on track. We will continue to rely on the shuttle for a majority or a good number of DOD payloads and of course we have reached an agreement with NASA on the shuttle manifest for the next three years. That was a result of negotiations between ourselves and NASA on priorities of DOD payloads and those which could go on expendables and those which had to fly at particular times.

That negotiation did result in an agreed to manifest for the next three years. We have expanded our Expendable Launch Vehicle production beyond that which was approved two years ago, the purpose of which is to work off the backlog that will exist as a result of the shuttle program being down and it will also result in reducing the demand for shuttle missions by the Department of Defense.

Of course, we have had to put some of the DOD Centaur missions on the Expendable Launch Vehicles after NASA cancelled the shuttle Centaur. We have had to move some of those payloads off. The Titan IV production has been expanded to 23 vehciles. As you may recall two years ago Congress did approve a limited production of ten which we then call Complementary ELV's which is now being called Titan IV, and that we are planning to have our first launch of the new Titan IV in late 1988. This is over a year and a half away. We are completing the nondestructive tests development process and requalification of the Titan 34D. As you know we had two failures, and we do plan to fly out the remaining six Titan 34Ds starting this year.

The recent successful launch of the Titan 34B, that is the core vehicle of the 34D was a positive first step toward the Titan recovery plan, and that was launched successfully on February 11th, just recently. The conversion of the Titan II to a space launch vehicle is progressing very well. It will provide the launch for a small payload starting in early 1988, and we currently have 13 conversions on contract and potentially will have 56 vehicles in our inventory to be used for space launch vehicles while only 13 have now been specifically idenified. I would anticipate that we will use a bulk of these boosters for space launch vehicles as we have done for the old Atlas ICBMs which have been fairly successful over the years.

After an intense competition for the medium launch vehicle, we selected the Delta II for launching our NAVSTAR Global Positioning Satellites, and the Delta II can provide as we required in our competition, a commercial variety and it will provide an attractive, low cost, and high availability booster for commercial applications. We have a contract with options to buy a total of 20 Delta IIs to deploy the GPS satellites.

We have initiated steps to redesign some selected payloads to be compatible with both the shuttle and the ELV to give us a higher confidence of getting into space for some selected payloads. We have also taken several steps to ensure that our launch pad capability is as robust and as flexible as our launch vehicle capability is soon to be. For example, we have looked at the total mission model for the Titan IV and we can justify an additional third launch pad for Titan IV launches. The best place that we felt to locate this additional pad is at Vandenberg Air Force Base, and we plan to build this new pad with a Centaur upper stage capability. We have asked the Congress for that in the budget that came over for Fiscal 1988 and 1989. The money is in for Fiscal 1989 to begin the construction of this new Titan IV launch pad at Vandenberg.

This plan, of course, by making the new Titan IV launch pad at Vandenberg, opens up the use of the launch complex 40 at Cape Canaveral for commercial Titan 34B launches. We have had indications from Martin Marietta that they do plan to commercialize the Titan 34D and the launch pad there would be available for that purpose.

The pad modifications are under way at Cape Canaveral for Titan IV complex which is launch complex 41, and starting at Vandenberg for a Titan II complex at what we call space launch complex 4 west. As we finished launching the Titan 34B vehicle on the 11th we moved right in to modify the pad at Vandenberg for the Titan II. The Delta II will use the existing pads at Cape Canaveral, complexes 17A and B. And of course if a Delta II polar orbit requirement did develop we have an option to convert an existing Delta pad at Vandenberg.

I think you can see when you look at the launch vehicle capacity: Titan IVs, the possibility of commercial Titan 34D, the Titan II, the Delta II, and the launch pad capacity that now will exist as a result of having launch pads for ELV's at both the west coast and the east coast as well as the shuttle pad at Kennedy, and then keeping the Vandenberg launch paid in a caretaker status that we can be activated at some time in the future. We will have a robust launch pad and launch capability for the future.

Speaking of the future, we do plan to implement the basic conclusions of the Space Transportation Architecture Study which we call STAS. We do plan for a low cost to orbit unmanned heavy lift vehicle, an a follow-on manned vehicle to replace the shuttle at some time in the future. That was the basic conclusion of the STAS effort. We are working with NASA and the Strategic Defense Initiative office to define the requirements for the heavy lift vehicle. Our objective there is to pursue the technologies now to define the vehicle in operational concept to significantly lower the cost per pound delivered to orbit.

And of course we have just established at Space Division a Heavy Lift Launch Vehicle Program Office to begin the studies necessary to define what that vehicle might be. We are also pursuing the technologies that could lead to the development of a National Aerospace Plane. I believe we have talked to this committee before on that issue. A joint program office is already in place and is working, and it is working together with NASA to develop the technologies that could lead to that capability some time in the future.

Finally, we have reached a tentative agreement on the pricing policy or the future shuttle missions flown by DOD and ELV missions flown for NASA. While we are still working out many of the details of that agreement it does consist of the following principles. The principles are that each party will pay for the hardware cost of the launch vehicle. What that means is that we will pay NASA for the hardware cost of launching the shuttle. If we launch an ELV for NASA they will pay us the hardware cost to procure that particular vehicle for them.

The launch services will be provided on a quid pro quo basis by the agency performing the launch. For example, if the NASA performs a shuttle launch for us they will pay the launch services after we pay the hardware cost. If NASA would like for us to launch an ELV for them we will pay the launch services for them while they pay the hardware costs. There is a quid pro quo on launch services between the two agencies.

There is a lot of details obviously associated with that dealing, but how does one go through the buildup or the transition, what if NASA requires an ELV that is not in the Air Force inventory? We will have to negotiate those on a separate basis, but I think in principle we are pretty much in agreement. And the last item is that based upon the reimbursements by DOD to NASA from prior years NASA owes DOD nine shuttle flights in the future. In other words, we have already paid for nine shuttle flights with the hardware for future launches.

Mr. Chairman, that is a very brief summary of the things that I have to say and I think after Mr. Myers presents his presentation I will be glad to respond to any questions you may have.

[The following information was subsequently received for the record:]

DEPARTMENT OF THE AIR FORCE
WASHINGTON D.C. 20330

OFFICE OF THE SECRETARY

Mr. Lloyd Beasley, Jr
Committee on Commerce, Science,
and Transportation
United States Senate
Washington, D.C. 20510

Dear Mr. Beasely:

Attached are six (6) questions for the record to be incorporated into the transcript from the hearing on NASA's Space Transportation Program before the Committee on Commerce, Science, and Transportation on March 5, 1987.

Sincerely,

DAVID L. VESELY, Colonel, USAF
Chief, Weapon Systems Liaison
Division
Office of Legislative Liaison

Attachment

SPACE STATION

QUESTION: Does the Department of Defense have any requirements for a permanently manned space station? What options for utilization of the space station are DOD assessing?

ANSWER: DOD has no mission requirements which would be uniquely satisfied by a permanently manned Space Station. We do envision the DOD as an occasional user of Space Station facilities as a platform for research and development or experimentation. However, we have not yet fully defined what these uses might be.

QUESTION: What are the implications towards the proposed space station of the recently announced DOD Space Policy that requires DOD "to actively explore roles for military man-in-space focusing on unique or cost-effective contributions to operational missions?"

ANSWER: The Space Station, as in the case of the Space Shuttle, could be utilized as a platform for exploring the potential utility for a military manned presence in space. Through the Military Man-In-Space initiative, we may find an operational role for military man-in-space.

QUESTION: Would DOD agree that no military activities should take place on the Space Station that violate the ABM Treaty? In DOD's opinion, could a "defensive weapon" such as a laser or particle beam be placed on the Space Station, and would the U.S. still be in compliance with the "peaceful purposes" provisions of the Outer Space Treaty?

ANSWER: DOD will fully comply with the tenets of the ABM Treaty. We have no plans for a laser or particle beam "defensive weapon" being placed on the Space Station. The military presence in space, established at the very earliest in this nation's space program, has been aimed at the peaceful uses of space. This nation has always maintained that the military use of space be consistent with peaceful purposes, since our space programs are intended for national security and defense. Both are permitted under the right of self defense contained in the United Nations Charter.

QUESTION: What role does the Secretary of the Air Force's Office have in the Space Station deliberations and in the current international negotiations? Who represents DOD at these negotiating sessions?

ANSWER: The DOD is represented by the Deputy Under Secretary of Defense (Policy) at the Space Station negotiating sessions. The Office of the Secretary of the Air Force provides assistance upon request.

DOD SPACE PROGRAM

QUESTION: Is DOD currently pursuing the development of an Orbital Transfer Vehicle? Is this a joint NASA/DOD program or a separate DOD program?

ANSWER: DOD is not developing an Orbital Transfer Vehicle to be used to accomplish substantial orbit changes such as with a large reuseable upper stage. The DOD is interested, however, in the NASA's procurement of the Orbital Maneuvering Vehicle to be used to facilitate inspection/maintenance/servicing/repair/etc. operations in proximity of DOD spacecraft. Current DOD involvement in this effort includes a DOD-funded task included in the NASA's Orbital Maneuvering Vehicle contract to identify design modifications required to allow the vehicle to satisfy specific DOD missions.

MIXED FLEET

QUESTION: Does the NASA/DOD quid pro quo agreement include Titan IIs, IIIs, IVs, and Delta IIs, or does it only include Delta IIs and Titan IVs?

ANSWER: The NASA/DOD quid pro quo agreement is still in negotiation and we are working toward resolution of these issues. Currently, we envision that Titan IV, Titan II, and Delta II would be a part of the agreement. Vehicles not in extended production or vehicles being phased out of the DOD inventory, such as Titan III, would not be included in the NASA/DOD quid pro quo.

QUESTION: Does this quid pro quo also resolve the Shuttle flight credit issue to the satisfaction of both agencies?

ANSWER: A satisfactory agreement on DOD flight credits has been reached. DOD has nine Shuttle flight credits booked with NASA against future missions.

QUESTION: The NASA Mixed Fleet Study shows that DOD will require the equivalent of 40 Shuttle flights in the period FY 1988 through FY 1995. It also says that these requirements through FY 1992 are "extra firm" because of the high backlog as well as other factors. Is this figure compatible with DOD's planning? How much of this 40 equivalent flight requirement is for missions or payloads which require the unique features of the Shuttle, and how much could be accommodated on other vehicles if they were available?

ANSWER: Before the recently announced change in the Shuttle launch resumption date, the NASA Shuttle Payload Flight Assignments Baseline (Oct 86) showed the following DOD flight rate:

FY 88	FY 89	FY 90	FY 91*	TOTAL*
2	5.33	5	2.33	14.66

*Thru April 1991

While firm DOD flight assignments beyond April 1991 had not been agreed to, the DOD flight rate was tentatively set at:

FY 91**	FY 92	FY 93	FY 94	TOTAL
2.33	4.66	5	5	17**

**May-Sep 1991

In these requirements, the DOD has some experimental missions that have been designed to use the Shuttle (e.g., SDIO experiments, Teal Ruby, CIRRIS, CRRES). Several national security payloads are also configured to fly on Shuttle. However, these and all DOD payloads could be reconfigured for launch on an expendable launch vehicle (ELV).

MIXED FLEET

The Impact to the DOD of NASA's latest announced slip (from Feb 1988 to Jun 1988) and a lower flight rate for the Orbiter fleet is under review. Additional expendable launch vehicles (ELVs) will be required to alleviate the mission impacts caused by the slip and lower flight rate. We will have the impacts and additional ELV requirements quantified by the end of July.

CONTINGENCY PLANNING

QUESTION: Is DOD developing any contingency plans for government payloads currently on the Shuttle manifest that are not Shuttle-unique e.g., DOD's Global Positioning Satellites?

ANSWER: The DOD has developed contingency plans for additional Shuttle stand down. The space launch recovery program funded 23 Titan IV launches through FY 93 for the Defense Support Program, Milstar, and classified missions. Launch projections through FY 95 require a total of 38 Titan IVs. If the Shuttle stand down is extended to 36 months, manifest planning indicates that an additional nine Titan IVs would be required through FY 95. A 48 month Shuttle stand down would require 20-25 Titan IVs in addition to the 38 now required through 1995. If a 48 month stand down is announced, detailed manifests will be developed. Eight Global Positioning System (GPS) satellites are on the Shuttle manifest. The GPS launches would be moved to Delta II if Shuttle stand down increases.

QUESTION: Is it true that the Air Force has agreed to intersperse commercial Delta II launches with the Global Positioning Satellite launches to try and promote a commercial ELV industry?

ANSWER: Since the production and launch capacity of Delta II boosters can be up to 18 per year once production begins and initial launch capability is reached, and Air Force requirements are 6-7 near term (four per year for replenishment in the out years), there is excess capacity available for commercial use. In accordance with the Commercial Space Launch Act of 1984 and the President's policy, this excess capacity is available for the commercial ELV industry on a direct cost reimbursable basis.

UPPER STAGES

QUESTION: What upper stage options are being pursued by both NASA and the Air Force? Are they being pursued jointly or separately?

ANSWER: As a result of the cancellation of the Shuttle/Centaur program, the NASA has requested three Inertial Upper Stages (IUS) to meet the interplanetary requirements for the Magellan, Ulysses, and Galileo missions. We are supporting their request and making arrangements to have IUSs available to meet their critical milestones. We are preparing to initiate the competitive procurement of additional upper stages for the Defense Support Program. This upper stage will be dual compatible with Shuttle and Titan IV and capable of delivering a 5250 lb payload from low earth orbit to geosynchronous orbit. We have asked the NASA to review their requirements and invited them to participate with us in this procurement if they desire. We have also invited the NASA to join us in development of a Shuttle compatible upper stage vehicle capable of delivering 10,000 lbs of payload to geosynchronous orbit. We welcome NASA's participation in these critical space system development efforts. A continuing, cooperative environment will return robustness to our national space program and ensure U.S. world leadership in space.

QUESTION: Can the high energy upper stage requirements of the Air Force respond to the requirements of the civil space program including planetary mission?

ANSWER: We are providing Inertial Upper Stages (IUS) for the Magellan, Ulysses, and Galileo interplanetary missions in response to NASA's request. It is possible other requirements could also be met by the IUS or other planned DOD upper stages.

Senator RIEGLE. Thank you very much.
Mr. Myers.

STATEMENT OF DALE D. MYERS, DEPUTY ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. MYERS. Thank you, Mr. Chairman. I appreciate the opportunity to appear here before you with Secretary Aldridge to discuss the space transportation policy issues. I have, a fairy short statement I would like to read because it does cover the policy issues that we have been very carefully dealing with. These include the status of the cost Challenger space transportation recovery system, the potential use of expendable launch vehicles NASA payloads, and our view of NASA's role in the development of heavy lift launch vehicles, and the next generation manned transportation system.

We have taken a number of steps to restore the Space Shuttle to safe, reliable flight. We have accepted and implemented the necessary changes required for a safe return to flight recommended by the Presidential Commission which investigated the Challenger accident. We have conducted a thorough reevaluation of all critical flight hardware and have identified and scheduled the changes that must be completed before first flight in the solid rocket boosters, the space shuttle main engines, the orbiter flight hardware and software and launch complex ground support equipment.

We have conducted a crew egress and escape system study and have initiated modifications which will enhance crew safety. We are also making a complete review of the total mission profile which includes pad activities, launch to orbit, and descent to landing. Finally, we have put a new management structure in place that will ensure improved program communications and management of the space transportation system. The Office of Space Flight has been reorganized consistent with the strengthening of the NSTS program.

We have made significant progress in the activities required to ensure the safe return of the shuttle to flight and have targeted the first flight for February of 1988. By the way, we set that schedule last June. While we are planning to that date, and developing all the elements of our program to coalesce to that date there are threats to meeting that schedule. We are making good progress currently, and our assessment is that the target date is achievable. However, I assure you that if we have any concerns at all about safety or there are any unforeseen problems, we won't hesitate to make the necessary schedule adjustments and change that flight date.

When we resume flying, shuttle performance will initially be limited to 55,000 pounds to low earth orbit from KSC and 21,200 pounds from the western test range, excluding mission reserves of 3,500 pounds. Landing weight is presently limited to 50,800 pounds. However, we do expect that a comprehensive load analysis now being conducted will permit an increase to 58,000 pounds in the near future. We are examining evolutionary improvements to obtain the performance equivalent to that planned prior to the accident.

An assessment of a safe, sustainable NSTS flight rate capability has been completed by both the National Research Council and the NASA STS flight rate capability working group. With a four orbiter fleet the NRC estimated the maximum sustained flight rate is between 11 and 13 flights per year. The NASA study estimated 14 to 16. The NASA planning goal is to build up to 16 flights per year from KSC in 1993. This will be reexamined after we have resumed shuttle flights and gained additional experience with shuttle operations.

We have authorized replacement orbiter production planning and critical subsystem procurement in order to effectively start production in August of 1987 with delivery in the spring of 1991. For the fourth orbiter these efforts will allow us the opportunity to get the maximum benefit to the nation through an early utilization of the orbiter to help fly off the tremendously large backlog of critical missions resulting from the *Challenger* accident.

We continue to provide launch services to reimbursable government customers on the Scout, Delta, Atlas and Atlas Centaur.

As you know, we have also been reviewing options for the use of expendable launch vehicles for some of NASA's science payloads. NASA initiated a study to determine the viability of a mixed fleet capability to launch approved and planned NASA and civil missions during the near term, 1987 to 1992, and are continuing to study the far term, 1993 to the year 2000.

The preliminary results of this study clearly indicates an unmanned expendable launch vehicle capability is absolutely required to augment the National Space Transportation system.

Further assessment of requirements for the Space Station assembly and logistics as well as other needs for heavy lift launch vehicles must be completed prior to a final decision on a total mixed fleet implementation plan.

There are some steps that can be taken now, however. We recently initiated procurement activity for a Delta vehicle to launch the NASA Cosmic Background Explorer or COBE mission in early 1989.

We have also identified candidate payloads for the Titan III and Titan IV classes that are under consideration for ELV launches in the period through 1991.

These include the TDRS E, as a backup to the TDRS's that we are lauching on the Shuttle; the TDRS F; the Mars Observer, the idea being here to advance this launch date to 1990; and two Explorer missions, ROSAT and CRRES.

We're in the process of establishing a joint NASA-DOD reimbursement policy. Secretary Aldridge and I have discussed that, and that process is basically complete. Some details are yet to be completed.

By the way, the fundamentals are agreed to. The details are things like, if they are out of production on the Titans, for example, there will be extra costs associated with the elements of maintaining—let's say amortizing the cost of maintaining the launch facilities themselves. There are minor elements that we're still discussing.

Those would be particularly applicable to the Titans and the Delta vehicles.

We support the President's policy on the commercialization of expendable launch vehicles, and NASA is proceeding to transfer authority to the private sector to use NASA controlled facilities and capabilities for commercial launchings.

We've actually completed our agreements with General Dynamics for the Atlas vehicles. We're in negotiations with McDonnell Douglas for the Delta class.

An agreement with Space Services, Inc., was signed in 1986, allowing use of NASA facilities for the launch of the privately developed Conestoga vehicle.

Martin Marietta has requested an agreement for use of NASA facilities in support of their commercial Titan program. They are currently reviewing a draft agreement which NASA provided them in December of 1986.

Today's U.S. space launch systems lack sufficient payload-lift capability, operational flexibility and operating economy to meet the national space launch goals in the late 1990s and into the next century.

It is very clear that the civil launch capability is not robust.

While the Space Shuttle, current expendable boosters, and boosters now in development will be the workhorse systems for the near term, both civil and military needs in the longer term will require new launch capabilities.

Early in 1985, the President directed DOD and NASA to jointly study the development of the next generation space transportation systems.

In September 1985, in response to the President's direction, the DOD and NASA initiated a joint space transportation architectural study. The study's completion is scheduled for late 1987.

The STAS is reviewing space transportation requirements for a wide variety of potential space missions over the next 25 years.

Potential mission scenarios range from a continuation of current national security and civil missions at a constrained level to cases where a substantial expansion, such as a full Strategic Defense Initiative deployment or an aggressive manned-exploration program, as proposed by the President's National Commission on Space.

The level of space activities is projected to grow significantly over the next 25 years. With that growth comes an increasing demand for reliable, cost effective access to space, and a potential need for much larger launch capacity.

Space missions are expected to grow in their diversity, increasing the need for operational flexibility and requiring new capabilities such as in the areas of servicing and maintenance.

Current space transportation systems lack the low operational costs, operational versatility, and the capacity to meet these future needs.

The STAS is considering both manned and unmanned systems, and a full range of options, including newly designed future systems, as well as ones derived from today's systems.

Architectural studies to date indicate that future needs can best be met with a mixed fleet of manned and unmanned launch vehicles, and orbital transfer stages based on advanced vehicle and operational technologies.

Although the study is not complete, preliminary results favor the development of an unmanned, partially reusable cargo launch vehicle to provide cost-effective heavy launch capability, this will be followed by a new, fully reusable manned vehicle as a post-2000 Space Shuttle replacement, providing both up and down mission capability and reusable orbital transfer vehicles.

This mixed fleet must provide reliable, cost-effective space transportation for a wide variety of space missions well into the 21st Century, and would be capable of capacity expansion to meet the demands of civil and national security missions.

We expect that NASA's involvement would include aspects of selection, development and use of heavy lift launch vehicles in the next generation transportation system.

These activities will encompass our long heritage in the development of large launch vehicles and their engines, as well as manned spacecraft, and the R&QA principles and practices required for manned systems, and as required, test facilities for booster structures, engines, and spacecraft.

We anticipate that the earliest requirement that NASA would have for a heavy lift launch vehicle could be as early as 1993.

The studies and analysis we are conducting with DOD to decide our next generation systems must be completed expeditiously to support future actions on new transportation options.

We believe it's important that existing, proven technologies be utilized where practical, and that opportunities offered by advanced technologies be understood; and that the most promising technologies be identified and developed.

Mr. Chairman, that concludes my prepared remarks. We'd both be pleased to answer your questions.

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR PRESSLER AND THE ANSWERS THERETO

Question 1: When will the Orbital Maneuvering Vehicle (OMV) be available, and will this be in time for the first anticipated servicing or reboosting requirement of the Hubble Space Telescope?

Does NASA intend to test the OMV in space prior to its first required mission, and, if so, how will these tests be conducted?

What consideration has been given to testing the OMV in a retrieval mission of the Long Duration Exposure Facility?

Answer 1: The OMV program has been delayed and restructured to support a first flight in November 1991. This is consistent with the Hubble Space Telescope program schedules which anticipates a reboost requirement in FY 1991. The Hubble reboost requirement is a function of solar flare activity which scientists believe will peak in 1991.

Studies are currently underway which should result in a plan to do a test mission of the OMV prior to the Hubble reboost if solar flare activity is less than anticipated.

An LDEF retrieval mission is currently under evaluation along with other candidate missions. However, LDEF is currently planned for recovery in November 1990 and OMV would not be available by that date.

Question 2: How much does the FY 1988 budget request provide for continuation of the Filament Wound Case Program; How much would be required to complete this program; and when could it be available for flight if an earnest attempt was made to complete and validate the design?

Answer 2: The FY 1987 Operating Plan includes funding to provide for closeout of the Filament Wound Case (FWC) Program by the end of this year. The closeout activities include completion of necessary structural tests, analyses, and documentation in a manner that would retain the option for program restart. The need to restart the program depends on the Air Force decision to reactivate Vandenberg as a Shuttle launch site.

Cost for redesign/certification and hardware production is currently estimated at approximately $180.0 million through 1992 to re-establish the FWC program and support flights beginning in 1992. Any decision to implement an Advanced Solid Rocket Motor program (ASRM) would consider avoidance of the need for the FWC performance improvements by providing the potential for even greater performance gains in parallel with the redesign effort to improve safety and design margins. A Phase B is planned to define potential ASRM's in preparation for a potential FY 1989 budget proposal.

Question 3: When will a decision be made concerning a Flight Readiness Firing (FRF) of the Shuttle's main engines prior to Shuttle Mission 26?

What would be the cost, schedule, and manpower considerations of this FRF?

What factors would argue against conducting a FRF before the next Shuttle mission?

Answer 3: The decision to have a FRF has been made. A preliminary assessment shows the direct cost for additional manpower, propellant, and other related items for a FRF prior to STS-26, are approximately $5 million. Required test planning, documentation changes (e.g., Operational Maintenance Requirements and Specifications Document (OMRSD)) would impact the existing ground flow plans and schedules. Based on preliminary information, approximately six weeks would be added to the flow time.

The main risk factor in conducting a FRF is the potential for launch facility and hardware damage. The KSC launch facilities were not planned for use as test stands that are designed to endure extended high energy source induced loads. We have conducted FRF tests in the past of the same duration we are planning. An additional schedule risk is completion of currently baselined Return to Flight Status (RTFS) modifications. This is due to the fact that the engineering workload for the existing staff would increase if a FRF was baselined.

Question 4: What progress has been made in resolving the problem associated with the crack that occurred in the aft skirt of the solid rocket booster last fall during a structural test, and will this problem be adequately resolved before Shuttle Mission 26?

Answer 4: The crack which occurred on the aft skirt was found to be caused by exceeding the weld strain capability. Detailed aft skirt structural analyses are now being performed by USBI (prime SRB assembly contractor), MSFC, Lockheed, and the Langley Research Center.

An aft skirt redesign concept has been accepted consisting of strengthening the area where the crack occurred. Analyses indicate this redesign will provide a positive margin of safety of 1.4 above the design factor of safety. Structural tests to verify this design will be conducted starting in August 1987, and will support the scheduled flight in February 1988.

Question 5: Previously undetected wind shear and negative margins of safety in the external tank attach rings have recently been mentioned as possible contributing factors to the 51-L Shuttle accident.

What are NASA's findings to date on these two factors, and what is NASA doing to resolve any problems or deficiencies that might exist in NASA's ability to adequately detect wind shear and in the weakened external tank attach rings.

Answer 5: The failure investigation team has found the failure of 51-L mission was caused by a faulty SRM O-ring joint. The wind shears present during the launch of 51-L were within acceptable Shuttle structural loads limits. The problem associated with the ET attach ring consists of failures of a few localized fasteners in the area of the ET attach ring away from the struts. A redesign is now in progress to eliminate the failures of these localized fasteners.

NASA has enlisted the meteorological expertise of the National Research Council to analyze what improvements, if any, can be implemented at KSC to heighten our forecasting capability within the dynamic Florida weather environment. More immediately, a wind profiler radar will be installed at KSC by late summer to supplement current Jimsphere balloon wind data measurements. The profiler will aid in shuttle forecasting and wind loads analysis for both the Shuttle and ELV's by providing real time insight into the prelaunch winds affecting the vehicles. In the fall of 1986, NASA and the FAA signed an MOU for a joint $5 million research project to develop technology for airborne wind shear detection and avoidance. The wind profiler and NRC study are a part of the overall OSF, STS Weather Forecasting 5-Year Improvement Plan.

Question 6: What are NASA's FY 1988 requirements and total cost projections for anomaly resolution and correction actions?

Answer 6: The following table summarizes the estimates for those tasks specifically identified as anomaly resolution/corrective actions and the Rogers Commission recommendations as they are included in the FY 1988 budget.

	FY 86/87	FY 88	BTC	FY 86/91 TOTAL
Anomaly Resolution	615	154	49	818
Rogers Commission	243	244	537-637	1024-1124

The range on runout of the Rogers Commission reflects uncertainty of the operations impact until we have achieved flight experience. Funding provides for requirements as they are currently defined. There may be potential impacts to the FY 1988 estimates from additional changes that may come out of the continuing systems review process and problems that may be incurred in the testing and certification of currently planned design changes.

Question 7: What does the FY 1988 budget request provide for establishing a second source for the Space Shuttle solid rocket motors and for preliminary work on a Block II solid rocket booster?

What is NASA's position on establishing a second source for the solid rocket motor that is currently being redesigned, and what factors will determine when and if such a decision will be made?

Answer 7: The FY 1988 budget request includes $10 million for studies and engineering analyses related to development of a second source and the Block II solid rocket motor. These funds will not support implementation of any major parallel effort for a second source or a new upgraded Block II motor.

An SRM Acquisition Strategy and Plan was prepared and submitted to Congress on March 31, 1987. This plan includes three options and reflects a proposal to implement Phase B design and development studies on an advanced solid rocket motor with the intent to include a potential Phase C/D implementation in the FY 1989 budget recommendation.

Question 8: What does the FY 1988 budget request provide for preliminary work on a liquid oxygen/hydrogen engine and for a second-generation Shuttle?

What factors will determine when and if either of these two projects are initiated?

Answer 8: Within the Advanced Programs (Advanced Transportation) area, NASA has requested $11.3 million to support continuation of studies and advanced development for future transportation systems including advanced liquid oxygen/hydrocarbon booster engine studies, advanced liquid oxygen/hydrogen engine studies, propulsion/avionics module studies, and advanced recovery system studies, all of which could be applicable to the development of a heavy-lift launch vehicle as well as a second-generation manned vehicle. In addition to these industry studies, NASA is conducting in-house studies of Shuttle-derived launch vehicles and next generation manned rocket vehicles. The need for a second-generation Shuttle is driven by the anticipated requirement to replace the current system as well as to achieve a more cost-effective system. NASA and DOD are conducting joint studies on future space transportation architecture and are preparing a joint report on an Advanced Launch System.

Question 9. The March 2 edition of Aviation Week and Space Technology states that Rocketdyne is proposing a number of changes for the Shuttle main engine that are designed to eliminate turbine blade cracks, reduce maintenance, improve production and extend engine life.

What specifically are these proposed changes, what factors will determine if they are adopted and implemented, and what will be the costs associated with implementing these changes?

Which of these changes are considered essential for implementation into the main engine before the resumption of Shuttle flights?

Answer 9. There are currently 20 mandatory changes planned to be implemented on the SSME prior to the first flight. All of these changes have to be certified prior to incorporation. On some key items like the turbine blade improvements, back-up designs and fall back positions are planned. These 20 mandatory changes are listed:

SSME MANDATORY CHANGES SCHEDULE

1. High Pressure Fuel Pump-Incorporate Phase II Mods - Complete
2. High Pressure Oxidizer Pump-Incorporate Phase II Mods-Complete
3. Nickel Plate MCC Outlet Neck
4. Incorporate Hydraulic Actuator Cleaning and Coil Redesign
5. Incorporate Changes to Reduce HPFTP Coolant Liner Pressure
6. Rework Main Injector Lox Inlet Manifold Seam Weld
7. Add Main Combustion Chamber Bust Diaphram Vent Drain Line
8. Modify High Pressure Fuel Duct Flanges and Reduce Pre-load to Prevent Leakage
9. Increase Helium Purge Frequency Downstream of Main Fuel Valve to Prevent Ice Buildup During Pre-launch
10. Add Redundant Skin Temperature Sensors to Anti-Flood Valve
11. Install Replacement Delay Lines, Ladder Switch and Diode Blocks
12. Replace FASCOS Hybrid Circuits to Prevent Erroneous Engine Shutdown
13. Revise Software Baseline to Incorporate UCR Fixes and Requirements Changes
14. High Pressure Fuel Turbopump First Stage Blade Fir Tree Lobe Improvements
15. High Pressure Fuel Turbopump Second Stage Blade Face Improvements
16. High Pressure Oxidizer Turbopump First Stage Blade Shank Improvements
17. High Pressure Oxidizer Turbopump Bearing Temperature Margin Demonstration
18. Low Pressure Oxidizer Turbopump Bearing Temperature Margin Demonstration
19. Improved Reliability Hot Gas Temperature Sensor
20. Reduce Degradation of Helium Purge Check Valve During Mainstage

Question 10: The FY 1988 budget request for Shuttle Production and Operational Capability, $1,229,600, is significantly less than the FY 1987 appropriation of $3,105,000. Generally, could you explain why the requirements are so much lower in FY 1988 than FY 1987?

Answer 10: The FY 1987 appropriation included $2,100,000 for full funding of the replacement orbiter. With that adjustment the FY 1988 request is actually higher by 224,500. These additional funds are to complete the recovery activities, to support the alternate engine turbopump activities, to start a second set of structural spares and to accommodate additional improvements that may be identified during the redevelopment test program.

Question 11a. What is NASA's plan to use its current store of orbiter structural spares for the replacement orbiter?

Answer 11a. The plan is to use all the existing structural spares for the replacement orbiter.

Question 11b. What plan will be implemented to restore orbiter structural spares that will be used for the replacement orbiter.

Answer 11b. The budget for FY 1988 and outyears includes funding to replace the structural spares.

Question 11c. What is the funding profile for this plan and what is the total projected cost to restore these spares?

Answer 11c. The estimated funding profile and total cost is:

(Dollars in Millions)

FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	TOTAL
$79	$65	$125	$105	$116	$490

Question 12a. When do you expect to sign a contract with Rockwell for the replacement of the Shuttle Challenger?

Answer 12a. The contract for the replacement orbiter is scheduled to be signed on August 1, 1987.

Question 12b. Will the $2.1 billion provided in the FY 1987 Continuing Resolution appropriation bill support completely this replacement activity?

Answer 12b. The $2.1 billion will support the currently defined replacement orbiter i.e., OV-104 configurations with some change traffic and the use of the previously approved structural spares. The funding for replacement of the structural spares is included separately in FY 1988 and subsequent budgets.

Question 12c. What is the funding profile for the replacement orbiter activity?

Answer 12c. The estimated funding profile for all replacement hardware pending contract negotiations is:

(Dollars in Millions)

FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	TOTAL
$60	$505	$718	$584	$206	$27	$2100

Question 13: The FY 1988 budget justification states that a "kit" will be manufactured to allow the modification of a Boeing 747 into a second Shuttle Carrier Aircraft.

How much will this "kit" cost, and what will be the funding profile and total cost to modify this Boeing 747?

Answer 13: The 1988 budget to Congress contains $32 million - $10 million in FY 1987, $17 million in 1988, and $5 million in 1989 - to procure the "kit" to modify a Boeing 747 (-100 series model) into a Shuttle Carrier Aircraft (SCA). This cost includes design, manufacture and installation costs. The cost of the 747 would be in addition (estimated to be $18 million to $20 million). The ready availability of a completed kit would significantly reduce the time a second SCA would be available in the event of a problem with the SCA now in the program. It is estimated that with a kit a second SCA would be available in 6 to 9 months vs. 21 to 24 months without a kit. Note, however, that the procurement of a second SCA is not budgeted for at this time.

Question 14: How many items are under review in the Failure Mode and Effects Analysis and the Critical Items List, and how many of these items will require corrective action, and at what cost?

How many of these corrective actions are necessary before the resumption of Shuttle flights?

Answer 14: There are on the order of 10,000 items under review in the Failure Mode and Effects Analysis (FMEA) and Critical Items List (CIL). The FMEA is an analysis that identifies the worst case effects of each potential component failure mode. The CIL is derived from the FMEA and documents those items classified as critical to life, vehicle or mission.

Grouping together the items identified in the precursor System Design Reviews (SDR's), the FMEA/CIL reviews and other separately identified items; a total of 362 changes or corrective actions have been identified for return to flight. Excluding the cost of the SRM redesign, the cost of these changes is estimated to be approximately $500 million dollars. All costs are included in the FY 1988 budget request.

Out of the 362 changes identified to date, 198 are designated as mandatory for the next flight. These include 48 SRM/SRB, 20 SSME, 42 orbiter, 36 flight software, 44 facility and 8 external tank changes.

Question 15: What are findings and conclusions of the ongoing review of the Shuttle Processing Contract (SPC)?

What changes, if any, are anticipated in the SPC contract, and when will these changes be implemented?

Answer 15: The result of the review of the SPC was a decision by the NASA Administrator, announced on March 9, 1987, that the current space shuttle processing arrangement should be retained and strengthened.

Several specific actions identified by the SPC Review Teanm are in the process of being implemented. These include increasing and more clearly defining the roles of NASA/KSC and the Launch Support Services contractors in the management and oversight of shuttle processing, stressing SPC management emphasis on discipline and thorough documentation, and improving the SPC's training and certification program across all disciplines and functions.

There are no currently identified changes in the basic structure of the SPC. However, the SPC Review Team did recommend that KSC and MSFC examine SRB recovery, disassembly, and assembly operations as implemented under the SPC to determine whether the current processing arrangement should be modified. A joint KSC/MSFC team is examining this area in more detail, and will make recommendations to the KSC and MSFC Center Directors and the Associate Administrator for Space Flight in the near future. We will keep the Committee informed should this examination result in a determination that contractual changes are necessary.

Senator RIEGLE. Thank you, Mr. Myers.

Let me start out by going back to the GAO audit, that we had done, and which helps us establish the spending pattern over time in terms of the pattern of growth of the defense space program and civilian NASA program.

I'd like both of you to give me your own sense as to the dynamics that have driven these lines. As we look at this chart, it was in about 1982 that we reached a crossover point, where the growth in the defense space program exceeded the annual cost of the NASA space program.

And of course the defense program has been growing quite rapidly since that time.

Now Secretary Aldridge, you mentioned operations as one of the critical components that is causing this acceleration here of spending.

I'd like you, if you would Secretary Aldridge, and then Mr. Myers, to as best you can help us understand the dynamics of both these trendlines, and any relationship in sort of the overall trend and how we can plausibly and logically relate one to the other here, and where you think we can't.

In other words, I'd like you to help us understand what relationships there are and ought not to be inferred between these lines, please.

Secretary ALDRIDGE. All right, I'll try to do that. I have not seen the GAO report, so it's difficult for me to understand exactly what went into the numbers.

I would guess, taking probably the most obvious of those, is, SDI is probably included in those numbers in the out-years, which had not been any part of the activities in the near years.

Our ABM defenses and air defenses were incorporated in strategic forces and not in space, so to speak.

I would then say, taking the SDI out of the equation for the out years, that would tend to drive that sharp spike down somewhat.

But I believe the real difference in what's happening here is that while there was research and development going on in the Department of Defense in the near years, our space program was relatively small in the sense of operational requirements. They tended to focus on more national capabilities. A few early warning satellites. A few other types of satellites. Quite a few in command and control.

However if you look out in the future, there is a growing demand, and a growing necessity, to use space more in support of military operations.

We see a significant expansion in the navigation systems. We see a significant expansion in the command and control, communications, early warning, treaty monitoring, weather satellites; those kind of things and others that we cannot go into.

But more in terms of an operational focus, as opposed to research and development.

And with the sophistication of the satellites growing in terms of their capacity, they're trying to incorporate survivability to the extent that we can. And certainly, the cost to launch has been increasing.

The satellites, by being more sophisticated, heavier, tend to require larger and larger boosters, which are more expensive.

And so I think all of that is driving in an exponential way to drive the cost in the future up. But I think primarily it's because there is a growing need, a logical and explainable need, for the use of space in support of military operations that did not exist in the early/late sixties or seventies, and it's beginning to be used by our commanders; the GPS satellite is a good example. And improved and survivable command and control systems, which are certainly an element of deterrence.

Senator RIEGLE. Before going to Mr. Myers, would it be fair to say, then, in addition to what you've just said, that if you even were to set SDI to the side, that what has happened up until now, up through the 1987 point on these lines, that the items that have really driven that sharp cost rise and expenditure rise have come from the things you've just described. The way in which we now plan military strategy and carry it out from a DOD point of view is increasingly space based, and the sophistication is such that the costs of that are expensive, but obviously, the judgment was that these are the best ways to get those functions done.

Secretary ALDRIDGE. In some cases, they were the only ways to get those capabilities. I'd say, yes, that's generally true.

I'd caution a little bit. I would expect that those dollars are then-year dollars. If you tried to plot it in terms of constant dollars or constant buying power, you wouldn't see such a wide increase in that spike.

But I think that the trend you just explained would certainly be there. I know for a fact that space is the fastest growing element of the Air Force budget, because of the unique capabilities that space and space systems provide for military operations.

And in fact, it is the most economical way to get some of these capabilities.

Senator RIEGLE. Mr. Myers?

Mr. MYERS. Mr. Chairman, I'm impressed every time I see that curve on the NASA programs. The early part in the 1970 time period was the spike associated with Apollo.

After we started the Shuttle program, there was a depression of activities in terms of funding for the NASA program. I'm not really sure what caused that, except that there was a disinterest, apparently, that developed during the development of the Shuttle program.

I was amazed when I rejoined NASA to find how little we had continued to do in space technology, for example new propulsion systems, new materials, the activities that I had always found so strongly supported in NASA during the Apollo program, were gone, or not gone, but certainly suppressed.

Every energy, every dollar, every man had apparently gone into the SSME or some other part of the Shuttle program. And it was a bad time period for NASA. This Committee and others have done a good job of helping restore NASA, and we have now a healthy program.

But the problem is that now we're in a position that after that downer with the middle years with the Shuttle, we began to see some recovery and then had the terrible *Challenger* disaster.

The amount of money that has to go into returning the Shuttle to safe flight has clearly continued to impact other important elements of the program.

You're going to hear me today wriggling about the problem of funding our ELVs. We know we're short of ELVs. We know we need ELVs. We're going to be coming to you here at the end of this month with a proposal on what to do with the issue of second source or advanced solid rockets for the Shuttle.

We know we've got other threats of this nature ahead of us. We know that we should be reaching out in the space technology that can lead to new and advanced activities in the future for science, for micro gravity activities, for more knowledge of life science, for long duration manned flight.

All of these things are threats that disturb me when I see this flattening effect. You're going to find that Jim Fletcher and I are going to be doing everything we can in the future to clearly define the most cost-effective programs that we can come up with that still keeps this nation as a civilian leader in space.

I guess I look at that shadow only at the bottom line, and I don't like what I see.

Senator RIEGLE. We'll pursue that later.

Senator Danforth?

Senator DANFORTH. Mr. Myers, you say you're going to be wriggling on the problem of ELV funding. But it's my understanding that NASA has significant plans to expend money for expendable launch vehicles.

And yet there's nothing in the budget to support these plans. Is that right?

Mr. MYERS. That's almost completely right, sir. We had a little money we scraped up for the Delta that we're going to use for the COBE, which is a very important science mission.

We have done an expendable launch vehicle study, by the way I think somewhat late. I came here in October, and there had been a time period when Jim Fletcher and the people he had brought together, a tremendous group of people, were spending literally 16 hours a day, 7 days a week, in trying to set in motion the program to recover the Shuttle from its disaster.

We started that mixed fleet study sometime in the summer or fall of this last year. We now have sorted it out to where we have priority launches that we think are very important to be done on expendable launch vehicles, starting in 1989, and going through 1992.

It's not a very large number of vehicles, but we don't have the money in 1987 and 1988 to buy the early vehicles that are involved, and we're working very closely with the Air Force, and I think with some indications of progress, on a way to work those problems.

And it's a difficult problem, to find ways that we can get backups to our shuttle capability, and get ourselves into a more robust position as far as launch vehicles are concerned.

I can only say that in the 1989 budget we certainly will be aggressively pursuing funding for that activity. But we do not have it in 1987 or 1988.

Senator **Danforth**. Prior to the accident, you were dependent—or the policy of NASA was to basically rely on——

Mr. **Myers**. On the shuttle.

Senator **Danforth**. For the purpose of what?

Mr. **Myers**. As far as I know, no, not every, but almost every payload that was being launched in this country was being launched on the space shuttle.

And I don't think that's correct. And I think that our policy today of a mixed fleet for this country, where we have concurrent capability, is absolutely correct.

Senator **Danforth**. And that is your policy?

Mr. **Myers**. It is our policy at NASA. It is the administration's policy. And I wholeheartedly support it.

Senator **Danforth**. And you haven't provided for it in the budget. So you've reached an agreement with the Department of Defense?

Mr. **Myers**. No, where we stand is that we've identified a backup for one of our TDRS, tracking and data relay satellites. We've identified a requirement to move the Mars Observer forward two years to get it off quicker.

We then have another TDRS, and two science payloads in 1991 that we would like to launch. The problem is that these are three-year leadtime programs, and it takes funding in 1987 to be able to launch in 1990. We don't have the money in 1987 to do that.

Senator **Danforth**. But there is the agreement with the Department of Defense?

Mr. **Myers**. We do have an agreement on pricing with the Department of Defense. And if a program is in production, we not only work this arrangement that Pete talked about of quid pro quo payment of hardware. We also have an agreement that for vehicles in production, we essentially borrow a vehicle and pay them back later.

So we transfer funds to them one year prior to the launch. Unfortunately, there just isn't enough production of vehicles in the country to handle the problems at the moment. And we're still working on whether we can essentially double book payloads on an Air Force vehicle so that if one of his payloads continues to operate in space and he doesn't need to launch another one, we can grab it and launch it for one of our payloads.

That's the kind of problem we're having because this country has so few expendable launch vehicles available. And by the way, these are fairly heavy launch vehicles we're talking about.

Senator **Danforth**. Mr. Secretary?

Secretary **Aldridge**. Senator, let me also address that. The problem is that all the expendable launch vehicles that we have in being are those which will be in production. And very fortunately, 2½ years ago we got approval from Congress to begin production of those new expendable, heavy lift vehicles—or new expendable vehicles called Titan IVs. If it hadn't been for that, we would be in serious, serious trouble today.

But that is underway. The problem is that all those vehicles are dedicated and identified for operational launches. We are working with NASA to see if there's a possibility that we might be able to use one or more of those vehicles in the near term to launch the TDRS.

It is clear, however, that NASA will have to get the money to pay us back for that booster because we still have to launch our payload. We can maybe move it back a little bit, or as Mr. Myers says, double book it, so that if we get up to the point where we identify the need to launch either TDRS or the DOD payload, we can make that decision at that time.

But it is clear that NASA will require funds to purchase ELVs. What we're trying to do here is to allow them to meet their early time with an Air Force booster with an attempt to pay it back at a later time once the budget can be approved.

Senator DANFORTH. Thank you, Mr. Chairman.

Senator RIEGLE. Senator Hollings?

The CHAIRMAN. Well, how do you explain, you've got 43 or 44 on order, and you've only got one, Mr. Myers. Is that OMB?

I mean, you're telling us the need. You told us months ago, last fall we heard about this. And we still don't see even a request.

Is that line zooming up because the gentleman on your left is willing to ask and you're not, or how do I explain it?

Mr. MYERS. Could I try and then have Secretary Aldridge cover it?

The CHAIRMAN. Yes.

Mr. MYERS. Secretary Aldridge was one of the people that really understood the importance of concurrent launch vehicles several years ago.

The CHAIRMAN. So his request is with merit?

Mr. MYERS. His request was continuously pressed for some time, while the NASA policy was still to launch everything we had on the shuttle.

Once the shuttle disaster occurred, we put so much of our energy in to that issue, that I think we probably did not catch the 1988 budget.

We in my view, looking back, we should have aggressively been pursuing ELVs in the 1988 budget. We hadn't finished our study yet, and the study now is complete for our activities through 1992. We know exactly what we need; we just don't have the money for it.

The CHAIRMAN. Very good. Mr. Secretary, with respect to the redesign of the shuttle rocket booster, are we on track? Are we going about it the right way?

You've got a similar problem with the Titan. You've got a technique that you use over there, nondestructive evaluation, ultrasonic, that you're using on the Titans now.

Are we using the right techniques and the right approach, in your opinion, to get us back in space on the NASA side?

Secretary ALDRIDGE. Well, sir, I'd have to let NASA answer that question. They're the ones who are responsible.

The CHAIRMAN. I'm not looking at the responsibility. I'm looking, do you have any suggestions? This is a good time for you to make them to NASA.

You all are good friends. I'm not trying to get people in trouble. I'm trying to really get this thing back up in space as quickly as possible, and you folks seem to have some vision or foresight as Mr. Myers has just described.

Secretary **Aldridge**. Well, sir, there are some stones to be thrown both ways on this one. But on the Titan 34D failure, we did find some quality control problems.

And perhaps that was the result of the decision the country made many years ago to go to shuttle only, and some of the people who were working on those solid rocket boosters on Titans began to go look for other jobs, and maybe some of the quality dropped off.

And we're seeing some of the signs of that.

The design techniques that we have on the Titan 34D are significantly different than the design techniques on the shuttle; and the nondestructive testing is associated to a different approach to putting on the insulator inside the solid rocket case. We have to make sure there are no debondings of that, based on the technique that has been developed over 74 launches and many, many years.

We have gone through the nondestructive testing techniques; in fact, I think we've pushed the state of the art fairly far along in that technique of X-ray and acoustics and infrared detection.

We have passed on that information to NASA for their use as they see fit in the solid rocket boosters. But because these techniques of how they go about that are a little bit different, in some cases it would be applicable and in some cases it is not.

But we have shared those lessons learned and those scars with NASA as we're pressing on.

Senator **Hollings**. Well, that's good to know. That's what I'm really after.

Is there anything else that you can think of that would help us facilitate the launch of a shuttle? We're shooting, of course, for February of next year.

Secretary **Aldridge**. I think NASA is doing everything that we can think of in the Air Force to bring that as long as, of course, you know we sent one of our best Air Force people down to Kennedy to run the Kennedy Space Flight Center, an individual by the name of General Forrest McCartney, and he is a very capable individual who knows just about everything that's going on in the Air Force at the time and he should be able to apply those lessons to getting that shuttle off in February of 1988.

It is an extremely high interest that we get that vehicle off the ground at that time.

The **Chairman**. You folks are very incestuous, except when it comes to money. NASA gets short-changed every time.

Mr. Myers, do you have any suggestions to this Committee, how we could facilitate getting back up into space next February and keeping that on schedule? Is there anything this Committee ought to know about?

Mr. **Myers**. With respect to the nondestructive testing activity that Secretary Aldridge talked about, I am well aware of the continued communications that are going on between our materials people at Marshall and the materials people with the Air Force on that subject.

There is a really good communication in that area. Where it applies, we will apply it to the solid rocket boosters, but there are differences in the application of the insulation and the techniques that are used for that activity, so we will especially cover that.

As far as the real question of what can we do more to meet that date of February, you know, we have got a success oriented schedule. We do not have a lot of slack in that schedule like we used to in some of our scheduling operations.

These things have all got to test and test right, and so far they are testing right. We have some major tests ahead of us in the solid rocket booster in the new configuration. It is going to come up in the June time period and that is kind of when the rubber hits the road on whether we are going to be able to meet those schedules.

If we keep clicking off all these tests the way they are going, I think there is a fair chance that we can meet that February date because what it means to me is that we have not only analyzed it properly, but understood what we were going to get out of the tests and then get that out of the tests. If that all occurs, we are in good shape.

The **Chairman**. Are you using that ultrasonic, that nondestructive evaluation that is employed by the Air Force? Are you using that also at NASA?

Mr. **Myers**. We are looking at it as an application in Florida. We do not have it as a direct requirement for the program yet. We will continue to look at it.

Our insulation is put in a different way than theirs are, and we are able to do a test on that insulation different than they are able to do, but we are certainly keeping up with them on all respects of nondestructive testing ultrasonic, infrared and the other techniques.

The **Chairman**. Thank you, Mr. Chairman.

Senator **Riegle**. Senator Wilson.

Senator **Wilson**. Thank you, Mr. Chairman.

Mr. Myers, according to your testimony, NASA and DOD are establishing a reimbursement policy, one that will support DOD's use of the shuttle and NASA's use of the Titan IV and Delta II vehicles. Is this agreement consistent with the administration's policy encouraging NASA to procure the ELV's?

This is really an extension of Senator Danforth's remarks.

Mr. **Myers**. Yes, it is. We are planning in cases where we can bring into the flow of our activities a privately built launch vehicle through DOD's capabilities that is consistent with the policies concerning commercialization. In cases where there are no vehicles of that nature available, we will go to a private source and look for launch services.

I want to caution you on a point that I always bring up at this time. We are dealing with some very expensive payloads and we are concerned about the quality control and specifications and the ability of the commercial launch vehicle people to meet the reliability requirements that we need to have in space.

We encourage the idea, but we are cautious about the reliability that we get from those vehicles. So, our tendency is to be sure that we are able to monitor and understand what the commercial launch vehicle guy is doing in the process.

Frankly, when we deal with these very expensive payloads, if you lose a vehicle you lose a lot more than the payload in our case because almost always ours are one-of-a-kind payloads, and you lose the mission, the university support and the whole scientific community associated with that vehicle. So, we are extremely sensitive to very high reliability.

Senator WILSON. Secretary Aldridge, what Titan IV and Delta II hardware would you expect to be available for NASA in the future if it were to exercise its procurement options as outlined in the agreement? Aren't all of the Titan IV and Delta II's on order? Don't they all have payloads assigned to them now?

Secretary ALDRIDGE. Yes, sir, they do in the near term, but we are trying to get up to a production base of about six Titans a year, Titan IV's per year. If that was the case with the ongoing production line and NASA needed a Titan IV for launching, we could bring one of those off the production line and allow them to fly with it so long as they paid us back the hardware cost, and that is the agreement.

They would pay us the hardware cost one year prior to flight. But because we have an ongoing production line, it would be easy for us to do that. On the Delta II, the same type of situation would occur. Once we have built up in the near years to an ongoing production base, it would be easy for us to allocate those boosters to NASA.

Titan IV is fairly easy. Delta II is a little bit different. We will have on order approximately 20 Delta II's over the long term. We have a contract and options for other contracts, but the Delta II also would be available in a commercial application in the sense that you could fly commercial satellites.

So, we would have to decide the best way to procure a Delta II launch for NASA if they wanted to fly Delta II's. They have the option to go right to a commercial user to do that, or they could come to DOD, depending on what was in the best interests of the country and what was in NASA's interest.

Senator WILSON. Mr. Myers, has NASA made any determination as to its future heavy lift vehicle needs, and when that capability would be needed?

Mr. MYERS. We have had a study done on the use of a heavy lift launch vehicle for launching the space station, and by the way, the first studies had mixed results but we are continuing that study because if we can use a heavy lift launch vehicle for launching the space station and for logistically supplying it, it helps reduce the number of shuttle launches required in that time period and that happens to be a time period when the science community is still desperately backlogged as far as their payloads are concerned.

So, it is a very interesting possibility. It has a couple of other interesting options involved in it. One is, because it reduces the number of shuttle launches required to launch the space station, it also reduces the amount of in-space integration that is required to tie the various pieces together.

So, there are some options. There are some advantages from the safety standpoint. Now, where are we in that? We have really just started that study and we do not have it completed as a clear set of requirements yet.

We have just looked at the use of it for logistics resupply to the shuttle. It is not a final clear look there. We know there are many science planetary payloads that are getting right up to the limits of our present systems, and we are doing launches like Galileo that take six years to get out to their destination because we do not have enough power to put them up.

So, we have plenty of other elements that look like they are going to develop into requirements for a heavy lift launch vehicle. They are not all firm yet, but they are certainly moving in that direction.

Senator WILSON. Thank you, Mr. Myers.

Mr. Chairman, unfortunately I have got to go to another meeting but if I had the time I would have asked one other question which perhaps can be answered for the record.

Your comment in your written testimony, Mr. Myers, about the 25-year look taken in the STAS study, is that the growth that is expected will lead to a potential need for much greater launch capacity. I would be interested in having you elaborate upon that and would be particularly interested, as you might imagine, what it may portend for the facility that is in my state.

Mr. MYERS. A simple answer, Senator, is a return to the Moon or a Mars mission could require heavy lift capacity.

Senator WILSON. Thank you.

Senator RIEGLE. Senator Bentsen.

Senator BENTSEN. Thank you very much, Mr. Chairman.

In looking back at the December 27 Directive on Space Strategy signed by the President, that called for NASA not providing launch services for commercial loads or foreign payloads unless they had some unique, specific reason to be on the shuttle. Since that period of time, do you have any numbers that tell us where those commercial payloads have gone, either to domestic launch services—have they been making contracts with them, or are they going to foreign sources for that?

Mr. MYERS. Senator Bentsen, I really do not know. When we were taken out of launching of the commercial launch vehicles, we kind of lost track of it.

Senator BENTSEN. When you what?

Mr. MYERS. We were taken out of being involved in the launch of commercial satellites. We really have lost track of it. They don't talk to us any more.

Senator BENTSEN. And there is no effort on your part to try to steer them towards some domestic launch service?

Mr. MYERS. Oh, there probably was a lot of discussion about the opportunities available, but most of the commercial launch vehicle people knew exactly what was available in potential privatized launch vehicles. There were only a handful that could possibly launch those vehicles.

They are all the ones that we all know, the McDonnell Douglas, General Dynamics, and Martin Marietta launch vehicles.

Senator BENTSEN. Maybe someone on your staff could answer my question as to contracts being let to foreign sources or domestic sources. Do you have anyone?

Mr. MYERS. Chet Lee is here. Chet, could you give us an idea?

Mr. LEE. Yes, sir. Senator, we know that the People's Republic of China have signed a contract to launch a Western Union satellite previously scheduled to fly on the Shuttle. We also know that

Arianespace has signed agreements for launches of a GTE satellite, one and possibly two Hughes satellites, as well as, one and possibly two RCA satellites. All of these were previously scheduled to fly on the Shuttle.

Senator **Bentsen**. Was consideration given to what would happen to those commercial services as that decision was made not to take those commercial payloads?

Mr. **Lee**. Yes, sir. I have to assume that that was considered in the decision by the SIG, sir, but I was not a participant in that.

Senator **Bentsen**. It seems to me that we have an obligation to try to encourage the domestic service to the extent that we can, and that is supposed to be, I would think, one of the spin-offs of the incredible amount of money that we are spending in this kind of research.

Secretary **Aldridge**. Senator, maybe I can address—I recall back during the SIG process that there was a great deal of pressure, I think on NASA and on the community, to do exactly that, to force the commercial satellites off the shuttle to encourage the commercial launch business in the United States as part of the President's commercial launch vehicle initiative so that there would be that incentive, that contractors who have launched vehicles in the domestic United States would in fact be encouraged to enter into that business because these satellites would be coming off the shuttle to make room for scientific and military satellites that would not have flown otherwise.

Senator **Bentsen**. Mr. Secretary, what I am trying to get to is, was there any way that we tried to see that our domestic service had some kind of an edge or some kind of an entree in that regard, when we opened up this market?

Secretary **Aldridge**. Well, sir, there were some other initiatives that were ongoing at the time, one of which was in the Air Force, to develop the commercial variant for what we call the medium launch vehicle, to encourage them to have a variant that would meet DOD satellite requirements but also could meet some of these commercial satellite requirements.

We made that decision just a month or so ago, and that is now under contract. Do you understand now that the McDonnell Douglas people who build the Delta have about six inquiries with, in fact, checks in their hand from people who want to fly a commercial Delta?

Senator **Bentsen**. Let me make a point to try to illustrate and dramatize a bit how important it is to try to see if we can keep these domestic launches—there are numbers that say, for every three of these launchings that we lose to foreign launch services, it is the equivalent to the importation of 10,000 foreign cars here. I think that is something we can relate to and understand, what it means and how significant it is.

So, that is why it is a concern to me, in trying to see what follow-throughs are made to try to encourage the domestic industry. Some of us are quite concerned with that trade imbalance.

Secretary **Aldridge**. Senator, let me assure you that we are doing everything we can to encourage domestic commercial satellite launches, and we are doing so by providing range services, launch pad services, providing every incentive we can to make it attractive for these commercial companies such as Martin Marietta or General Dynamics or McDonnell Douglas or anybody else to do them.

Senator BENTSEN. Are we getting the same thing from NASA?

Mr. MYERS. Yes, we have worked out and negotiated a contract with General Dynamics, probably the first of the privatized contracts for use of the facilities that the government originally built. They can essentially lease those facilities from us for launching.

We are doing the same thing now with McDonnell Douglas and Martin Marietta is working with us to use some of our support services for supporting their commercial launches.

Senator BENTSEN. Well, I will be asking the same question toward the end of the year, and I hope you can give me more encouraging news.

Mr. MYERS. Well, the problem is, of course, that just as the big concerns at the time of that policy being established, having worked with the Chinese, I know that they can charge whatever they want to charge, and they can undercut prices dramatically if they wish.

I think that is a really serious issue in this whole business of commercial launches.

Senator BENTSEN. Thank you, Mr. Chairman.

Senator RIEGLE. Just on that point, before we move ahead, that is, is there any fixed agreement right now for a private commercial launches in this country? Is there anything nailed down?

Mr. LEE. Not that I am aware of.

Senator RIEGLE. I am not aware of any either. Let me ask you this, then. As long are none are nailed down, how soon is it feasible, as a practical matter, to imagine that one could be launched privately, a private sector launch?

If an agreement were reached, how far out are we talking?

Secretary ALDRIDGE. We are probably talking a couple of years.

Senator RIEGLE. Do you think it could really be done within two years?

Secretary ALDRIDGE. No, sir. Let us back up just a minute. The problem was that, one, we did not have the policy until, really, December. The other was that they had to go look for where the boosters were going to be.

We were in the process at the time of a competition in the Delta vehicle, for example, which had in the RFP a requirement that the bidder must have a variant of that booster to meet DOD demands but must have a variant capable of launching commercial satellites, and there were three bidders, Delta II, the Atlas Centaur, and the Titan 34-D.

The Air Force selected the Delta II to meet its demands, but it also met 70 percent of the requirements for commercial satellites at a very attractive price, even cheaper than Ariane, so there is a booster now available that is capable of launching 70 percent of the commercial satellites.

Now, also there is a plan we were working with the Department of Transportation and NASA, looking at a model contract, what kind of facilities could we provide these people without subsidizing. That is illegal, to subsidize.

There is a model contract now being worked and that is just about ready for completion, so now there is a definitive statement of what we will provide, at what cost we will provide it. Now they can quote a definitive price to these commercial people so they can in fact sign up.

Once they do, and as I mentioned, Martin Marietta has nine checks of, I believe, $100,000 each and 21 different inquiries about launching on Titan 34. The Delta has now been decided. There is a viable commercial Delta vehicle. They have six checks and with any number of people in there now talking to them.

So, finally, from the time we had the policy to now, we have finally got something concrete that these people can now grab hold of. We did not have it until just a few months ago.

Senator RIEGLE. We will come back to that. Senator Pressler has kindly agreed to let Senator Adams go next here because of the time pressure he is under.

Senator Adams.

Senator ADAMS. Thank you, Senator Pressler, very much.

Thank you, Mr. Chairman.

The question, the first one that I was going to ask that I consider of great importance, has just been asked and that is, how are you going to have a commercial operation when you are operating against two obviously subsidized countries who wish to be in this field?

Mr. MYERS. I think the best thing that is happening to our commercial launch vehicle capability right now is the contracts that are underway from the Air Force. It gives you a production run that reduces the price of those vehicles.

Senator ADAMS. Let me shift to that. Mr. Secretary, I am concerned about the space station, and I would like to know whether or not the Department of Defense has any firm requirements at this point, or a position that they need a space station.

Secretary ALDRIDGE. No, sir. There are no firm requirements. However, we cannot foreclose the possibility that sometime in the future there would be some experiments or some requirements that we may have on the space station. But I cannot tell you today that there is a definitive set of requirements or a definitive experiment or a plan, or an operational experiment we want to do on the space station.

Senator ADAMS. Let me tell you where I am coming from, which is that there are requests before this Committee to build a fourth vehicle to replace the one that is gone. To build a space station, in my opinion, you need heavy lift vehicles and you need the others as support vehicles for it; in other words, a different or new policy.

It is my understanding, Mr. Myers, that the space station, which is the next logical thing to be placed in space to match the Russians. The space station now has an option plan being developed at the White House. Isn't that correct, that it is being so done?

Mr. MYERS. Yes.

Senator ADAMS. And it is also my understanding that OSTP, OMB and NSC are producing those options, isn't that correct?

Mr. MYERS. There are meetings going on right now, I know.

Secretary ADAMS. But you are not involved in them, are you?

Mr. MYERS. I will be.

Senator ADAMS. Has NASA been involved in them?

Mr. MYERS. We have been.

Senator ADAMS. Are you involved in the group that is making the decision?

Mr. MYERS. Yes, in the sense that we will be involved at the time they come up with their options, based on our data and reviews with them.

Senator ADAMS. If it were decided in the next week or two weeks, would you have been in it?

Mr. MYERS. Yes.

Senator ADAMS. In other words, you have to get in it in two weeks and you have not been in it before?

Mr. MYERS. We have been in it. We have been involved with all three of those groups in briefings.

Senator ADAMS. You have been involved with the groups, you have been with the groups as you formulated the plan?

Mr. MYERS. I have not been, with this meeting that is going on today.

Senator ADAMS. You have or have not?

Mr. MYERS. Have not, although I might add that we have supplied data to that group.

Senator ADAMS. Now, Mr. Secretary, it is my understanding that we are talking about ELVs, that you can pull Titans out of the silos and convert them for lift vehicles. But it is also my understanding that this is supposed to require two and a half years.

Is that correct, that it takes two and a half years to create a lift vehicle using an already existing launcher that you are replacing?

Secretary ALDRIDGE. Yes, sir, it does because you are taking a vehicle—you have to make sure that all the components that you pull out are reliable. Then there is a change in some of the guidance techniques and there is a change in the shroud, and then there has to be an interstage structure to carry the payload and a complete re-check of the vehicle to make sure all the components are correct.

It does take that long, but it is the time you pull it out of—the first one is the long time because that goes through the basic development. Once you do that, it is probably about a two-year time from the time that you decide to launch it to the time it actually can launch.

We are about a year and a half—no, we are about a year away from a launch at this point.

Senator ADAMS. My final question to both of you, because my time has run out, is this. I am very much in support of the space program, and a space station, but I have to admit that I am appalled at the attention being placed on such things as commercialization, when we do not really have the ability to move into space and do the basic things like creating a space station at this point.

From what both of you have testified to, we have almost no available unmanned launch vehicles, and that it will take approximately two years before we are back in at all. Is that correct?

Secretary ALDRIDGE. I do not think that that is a correct statement, we have no unmanned launch vehicles. The problem is we did have two failures in the large capacity unmanned vehicles, the

Titan 34D. But we just launched in February 11th a Titan 34B, which was——

Senator ADAMS. Maybe I put it too strongly, Mr. Secretary. There have been very, very few and not the capacity to move, for example, to any kind of a space station program with any kind of major heavy lift capacity for at least two years plus?

Secretary ALDRIDGE. Senator, in 1978 this country made a decision that said the shuttle is going to be the exclusive launch vehicle for the country. That was a tragic mistake, and from that point on—we have just two years ago changed that policy.

And now we are in a lull. Not only are we in a lull with regard to launch capacity; this failure has even caused us to be in a more serious condition of no shuttle launches and no Titan 34 launches.

We are in a problem right now with launch capacity, and it was because of the decision we made in 1978. If we had kept on with the expendable launch vehicles with a mixed fleet strategy that we now say is correct, we would be in a more robust situation today for launching capability for space.

That does not address the problem of the space station. That is some time downstream.

Mr. MYERS. Let me speak to the space station. The space station needs its launches in 1993. The shuttle is fully capable of launching and erecting the space station. The problem is when you use it for that you have other payloads that are in this backlog that we ought to be getting off.

So we are going to be looking for more expendable launch vehicles. We need a more robust capability.

Senator ADAMS. Thank you, Mr. Chairman.

I would like to pursue it further. But Mr. Secretary, I thank you for your statement. I think the policy was not only tragic, but for the last four years the pursuit of goals such as excessive commercialization, relying on one vehicle, or even the replacement of it at the expense of launch capacity, is putting us behind the rest of the world, not only in our regular satellite, our military, but in moving forward to space station.

So I am hopeful this committee, Mr. Chairman, will be concentrating on utilizing the funds we have available to get our launch capacity up to a point where we can be in space and not just talking about it two and a half years out.

Thank you for your courtesy, Senator Pressler. I appreciate it.

Thank you, Mr. Chairman.

Senator RIEGLE. Senator Pressler, you I think have an opening comment that you want to make and why do you not make that now. And then when you finish, proceed with your questions.

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. Thank you.

Today's hearing is significant in that it focuses on the cornerstone of our nation's endeavors in space—safe, reliable access to space.

If we have learned anything from the Challenger accident it is that we must never again rely on a single-point failure space launch system. The hiatus in space launch opportunities and our future constrained launch capacity point out all too clearly that in the future we must maintain a robust, flexible "mixed fleet" of Shuttles and expendable launch vehicles (ELVs). We are paying the price, and will for some time to come, for the shortsightedness of our previous space launch policy.

Unfortunately, NASA has not yet submitted its ELV requirements to the Subcommittee. Certainly, establishing a mixed fleet will not be without significant costs. Yet, this is an issue that must be resolved soon, as there are several other issues that are awaiting the resolution of this ELV issue.

NASA must enunciate clearly and soon its future ELV requirements, for the next couple of weeks, the FY 1988 Congressional budget process is expected to begin, with the Senate Budget Committee markup. NASA's chances of receiving additional funds for the procurement of ELV services will improve if NASA makes it requirements known at the "front-end" of this process.

Today's hearing will provide the Subcommittee with another opportunity to monitor the progress of NASA's Shuttle restoration activity. Furthermore, this hearing will help the Subcommittee determine the adequacy of NASA's FY 1987 and FY 1988 budgets to support the Shuttle restoration effort and other Shuttle-related programs and activities.

Mr. Chairman, I intend to explore in some detail what has been discussed, but I also intend to pursue more the current positions of NASA and the Department of Defense regarding the development of a heavy lift vehicle, as well as to what extent these two space programs are attempting to coordinate their respective HLV efforts. Even though NASA and DOD may have different heavy lift requirements, it is important nevertheless that we avoid unnecessary duplication as our country pursues this capability.

Finally, the presence of the Office of Commercial Space Transportation of the Department of Transportation at today's hearing underscores the significance of our emerging commercial ELV industry to the discussion of space launch policy. By most accounts, some of our U.S. ELV systems are establishing a growing customer base. It is important that our nation's space launch policy takes into consideration the role of the U.S. commercial ELV industry in our overall national space launch infrastructure and capability.

With these thoughts in mind, Mr. Chairman, I, also, welcome to the Subcommittee hearing Secretary Aldridge of the Air Force, Mr. Myers, the Deputy Administrator of NASA, and Mr. Stadd, the Director of DOT's Office of Commercial Space Transportation.

Let me ask you, Secretary Aldridge, the shuttle launch complex as I understand it, the Vandenberg Air Force shuttle launch complex, is under minimum caretaker status until at least 1992; is that the current plan? Is that a correct statement?

Secretary **ALDRIDGE**. It is under a minimum caretaker status until we make a decision to reactivate it. At the time of the decision to reactivate, we are four years to launch.

Senator **PRESSLER**. What will be the annual operating costs for maintaining this launch complex under minimum caretaker status, the activation costs, the cost to operate it under an "all-up" conditions?

Secretary **Aldridge**. All right, sir. The current operating plan would be to operate it at about $50 million a year. That is around 50, 5-0, million dollars. But any time during that—that would be to keep the facility in such a status that we could activate it when the requirements dictated in about four years.

To build up from that $50 million to the time of launch in about four years would get you up to an annual operating cost of about $400 million a year. So depending on the buildup rate that you could achieve by hiring people, you can estimate that the cost to activate until you got to an operational capability would be about a billion dollars, getting to that $400 million a year annual operating cost.

Senator **Pressler**. Secretary Aldridge, what shuttle lift performance will the Air Force require before it activates the Vandenberg shuttle launch complex?

Secretary **Aldridge**. Sir, our plan at the time we were planning to fly shuttles out of Vandenberg required 109 percent thrust level on the shuttle main engines and the filament wound case for a majority of the DOD missions. However, there could be other missions that could be flown without having that performance, such as if some SDI missions, some experimentation missions, or perhaps some space station resupply could be flown with performance levels less than that.

But for a majority of the DOD missions, it would require the 109 percent and filament wound case and some other safety waivers that would be required, such as landing weights and things like that, which are being discussed now with NASA.

Senator **Pressler**. What are NASA's plans for completing the development of the filament wound case, and to what extent is this development dependent on the solid rocket motor redesign? And similarly, what plans does NASA have for achieving a shuttle main engine power rating of 109 percent?

Secretary **Aldridge**. I will pass that to Mr. Myers.

Mr. **Myers**. We of course are doing our qualification of the SSME now with a whole series of tests that have been planned now and in the future prior to launch. Our qualification level is 104 percent. NASA does not have a requirement for 109 percent on the East Coast.

We do, however, plan to enter a 109 percent, an over-RPM, overthrust test program, whether or not there is a West Coast requirement. We want that for knowledge of the expansion of the envelope of the engine from a safety standpoint.

So what we have told Secretary Aldridge is that when he decides to crank up the West Coast, that four year period is sufficient time to do 109 percent qualification of the SSME and the completion of the development program on the filament wound booster that we already had started. So we just have that in standby, ready to do that when a decision is made to crank up the West Coast.

I want to repeat the point, though, that we do want to do testing on above 104 percent on the SSME just to give us more margin of safety.

Senator **Pressler**. Now, Mr. Myers, following up on that, NASA's space station plans obviously call for West Coast shuttle launches for manned servicing of the space station polar platforms.

How would the absence of a West Coast shuttle launch capability affect this aspect of the space station or, for that matter, any other NASA program?

Mr. **Myers**. Well, the absence of a West Coast facility would be, I think, a real blow to the polar orbiter that we have as part of the space station. We have found that the servicing of these major observatories in space is a really incredibly important part of the observatories.

The Hubble Space Telescope, which will be the first of these man-tended laboratories, is dependent on man for replacement of sensors and for operating of the equipment. It would be a really dramatic blow if we lost that capability on the West Coast.

Senator **Pressler**. Secretary Aldridge, with the termination of the Shuttle Operations Planning Complex and the decision to build a second Titan launch pad at Vandenberg there is the appearance—and I emphasize, appearance—that the DOD is pulling away from the shuttle.

Could you comment on this again and on DOD's commitment to eventually fly the shuttle from the West Coast? Does DOD require a West Coast shuttle launch capability, and, if so, for what purposes?

Secretary **Aldridge**. I will address the SOPC question, yes. There was a decision to terminate the shuttle operations and planning complex at Colorado Springs because, with the reduction in shuttle flight rate down on the order of 16 flights a year, it is the opinion that NASA could provide that capability at Houston with the DOD still flying, as we had committed to before, about one-third of the shuttle missions, somewhere between four and six.

It is our intent to continue that commitment to about one-third of the shuttle missions for the future. The launch pad at Vandenberg is based upon the fact, even with flying one-third of the shuttle missions—I may point out, that is one-third of the shuttle missions over the long term in a steady state.

During the first few years of shuttle flight, we will be at a higher percentage because we have so many payloads backlogged on the ground that are operational missions. So it will be higher than the one-third in the near years, but over the long run about one-third.

With the movement of the other missions off the shuttle—recall we were planning 24 missions per year on the shuttle, of which the DOD was going to fly about eight to ten. Some of those had to come off because of just the flight rate. Some had to come off because of performance. Others had to come off because of the shuttle-Centaur cancellation.

When we look at the number of Titan IV's to be launched for the future, in addition to that which would be committed to the shuttle, we could justify three launch pads. We do not have the flexibility with only one launch pad on either coast. A third launch pad was required.

The best place to put it was at Vandenberg because of the inclinations that we would be flying out of there, and we would also give it a Centaur capability for the purposes of launching higher inclinations, high altitude vehicles.

So we are still committed to the shuttle. We are still committed to one-third. But with the missions that we have had to pull off of the orbiter for the purpose of DOD requirements, we need the third launch pad somewhere, and Vandenberg was the more likely place to put it, where there was facilities and land available to do that.

But with that and with now the fewer flights that existed, military flights on the shuttle, there was not as strong a requirement for the SOPC, the shuttle operations and planning complex, that existed when we were going to fly eight to ten per year.

That DOD requirement can be maintained by the Houston complex at Johnson.

Senator PRESSLER. Thank you, Mr. Chairman. I have another round of questions after everybody else finishes.

Senator RIEGLE. Thank you. Very good.

Senator Gore.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. Thank you very much, Mr. Chairman.

Mr. Chairman, I want to commend you and the staff for the timely scheduling of this hearing focusing on some of the most crucial questions that must be answered if we are to define a coherent United States space policy.

In the context of hearings on the NASA Space Transportation System budget request for 1988, we must carefully examine the funding of space programs not only in the NASA budget but in the Department of Defense budget. Careful attention should be given to the predicted launch demands of NASA, DOD, and the private sector. The requirements of each should be separately identified in terms of the transportation systems necessary to meet these needs.

As a member of the Armed Services Committee, I am particularly concerned about the current level of cooperation between NASA and DOD. I pointed out in earlier Subcommittee hearings on NASA's budget that there are serious concerns regarding the Heavy Lift Launch Vehicle program. To what extent can the program be justified by the projected requirements of NASA, DOD, and the commercial markets? How can we insure that there will not be costly duplication of NASA's expertise in propulsion technologies and its facilities, particularly in the research and development phase of the HLLV program, if DOD remains the lead agency?

Finally, inherent in these and other questions which the Subcommittee must address, is the need for a coherent overall plan for our national requirements in space. Without a new space policymaking apparatus within the executive branch, I am doubtful that we will ever sort out the complex questions regarding space transportation needs which, after all, can only be answered when we have defined a comprehensive national space policy.

I would like to welcome both our witnesses. I have got a number of concerns and questions here. One set of questions has to do with the requirements for an HLV. Another set of questions has to do with who is going to take the lead and how is it going to be developed. And another set of questions has to do with the effort to force technology and skip a generation of vehicles, the shuttle-derived vehicle. I hope I will have time to explore all three areas, if not on this round then perhaps we can pursue it further later.

To begin with, it was my understanding that when DOD was given the lead role on the national aerospace plane the common assumption was that NASA would have the lead role on the heavy lift vehicle. I mean, these are the only two projects coming down the pike for the future space program.

And if DOD is going to be given both of them and the shuttle has a 100-flight lifetime, then we are looking at closing NASA's doors at some point in the not too distant future and just make it all military.

Am I wrong in saying that the common assumption was that NASA would be playing the lead role in the development of the heavy lift vehicle, Mr. Myers?

Mr. **Myers**. I do not think it was ever decided, but certainly NASA has a tremendous capability in heavy lift launch vehicles. We were the ones that built the Saturn I, the Saturn I-B, the Saturn V, and the shuttle. They are all the heavy lift launch vehicles of this country. We have the test stands, we have the manufacturing capabilities, we have the people, we have the project management capability.

It is a little different in my mind than the case of the aerospace plane. In the case of the aerospace plane, that is more like the X-15, where there was an airplane-type capability within the Air Force and there was a technology capability in NASA that stems clear back to the old NACA days.

Now, having said that, the fact is that the requirement that has developed is to the place where we both need to understand what the requirement is, and we in NASA have not really nailed down our requirement for the heavy lift launch.

Senator **Gore**. In other words, along came Star Wars, and the heavy lift vehicle is held out as the magical hope for reducing launching costs by a factor of ten. And the Air Force projects heavy use of this vehicle.

But that still does not answer the question, because with other programs you have clearly anticipated that the user will be another agency and yet NASA has retained the lead role in the research and in developing the vehicle and then they would turn it over to the agency that is going to be the lead user.

I mean, take the weather stuff with NOAA. You have turned over programs in the past after you have used NASA's expertise in behalf of the country to develop it in the best and most efficient way.

So I am troubled. Now, METSAT and LANDSAT are the two systems that I am referring to. You were the lead role in developing both of those systems, even though you knew you were not going to be the operator when they were finished. Correct, Mr. Myers?

Mr. **Myers**. That is correct.

Senator **Gore**. Well then, why should the Air Force be given control of this whole development program when you have got the test stands, you have got the expertise, the people, the R&D capacity?

You know, Secretary Aldridge is waiting for a chance here.

Secretary **Aldridge**. I am starting to stand up.

Mr. **Myers**. Senator, let me close my comments——

Senator **Riegle**. He was about to launch.

Mr. **Myers**. Let me close my comments before my friend Pete comments.

We have been working with the Air Force, as you know, on the STAS program for some time. As the heavy lift launch vehicle came into focus, the project office was established on the West Coast or is being established on the West Coast. The involvement of NASA has been invited. We are in the process of developing our ideas in that area, and we are going to be getting with Secretary Aldridge shortly on that issue.

I think he fully expects to use the capabilities of NASA in the program. We have talked about it as late as a few days ago.

Senator **Riegle**. Senator Gore, I think this is a very important line of questioning. You are right in the middle of it. Why do you not use my time period now and I will follow Senator Pressler.

Senator **Gore**. You are very kind, Mr. Chairman. I have got to go to the Armed Services Committee to meet with some other Air Force types.

Secretary **Aldridge**. Please do not ask any B-1 questions.

Senator **Gore**. I would like to know who had the lead role on that one.

Go ahead.

Secretary **Aldridge**. Senator, it is not a black or white issue. In the National Aerospace Plan, it is a joint program. It is a national program. NASA is deeply involved.

Senator **Gore**. Well then, you would not mind if NASA took the lead role, then?

Secretary **Aldridge**. I would mind, because I think in these programs the requirement in terms of the heavy lifters is dominated by the Department of Defense requirements. That is where the money is going to have to come from. It is going to be DOD requirements that are going to pay for those things, and we feel that we need to be in the lead.

Now, there is a caveat to all of that, because I do not know what a heavy lifter looks like. If a heavy lifter is a derivative of the shuttle, where the expertise in NASA is there, I have no requirement in NASA being the lead on something like that, because they can just carry it forth from where they stand.

However, based upon the studies we did with NASA on the other side—and again, this is a joint effort that we undertook, per the direction of the President, called the space transportation architecture study. It is a joint study. I was the co-chairman at one time on that with Jess Moore, looking at what the future, the second generation space transportation system ought to look like.

The general conclusion of that study was that we needed to get on with a series of additional and future boosters, in which we focused on trying to get the cost to launch down. That was absolutely agreed to, that we were spending far too much money for the standing armies and what we were doing on launch costs.

So what can we do in the future to get the costs to launch down? And the conclusion of that study was that we needed to take two approaches: We needed a heavy lifter and we needed a follow-on to the shuttle.

And we ought to begin working on technology now on those two directions so that we could get the cost to launch down.

Senator GORE. Finish up briefly.

Secretary ALDRIDGE. But the new technology was such that we were focusing on a 1997 capability for a heavy lifter with these new technologies. It would not necessarily be shuttle-derived. We felt that was the wrong answer because there were too many operational concepts which were too expensive in the shuttle.

Now, if it is a new technology focused on DOD requirements and DOD operational needs for the future, then we ought to be in the lead for it, working with NASA, using their expertise. It would not be completely shoving them out the door.

Senator GORE. Well, let me just say that as a member of this subcommittee and also as a member of the Armed Services Committee, I disagree strongly. I think that NASA's expertise is not limited merely to shuttle-derived systems. I think that NASA's experience in bringing technology along is extremely impressive.

The fact that the next generation happens not to be a shuttle-derived system does not mean that NASA lacks the capacity to do the follow-on R&D work and development work for the third generation heavy lift vehicle. I think they clearly do.

I have been down to Huntsville recently and looked at all the capacity that exists there. And I want to underscore and refer to Senator Heflin's statement for the record, and I will put my own statement in the record on this point.

But it troubles me that the magic of Star Wars mathematics, where you have to have this extremely dramatic and unprecedented reduction in all of the launching costs and computer costs and weapons costs in a very short period of time, is being used to drive the technology development process in a highly unrealistic way, completely skipping the next logical step in the technology, which is the shuttle-derived vehicle, which has enormous capacity for heavy lift.

Now, I guess one clear thing that comes out of this hearing is that both of you seem to agree that, at least in the mid-term, there would not be a heavy launch vehicle except for the SDI program. If I can just be candid for a minute, my impression is that NASA said that it was not needed for the space station, largely because it did not want to absorb the cost in the NASA budget, and the space station was designed to be used with the current generation of launch vehicles.

Actually, it probably could serve a useful role in putting the space station up and would not involve an extensive redesign effort on the space station. But as a practical matter, without SDI there would not be a need in this century for a heavy lift vehicle.

So when we examine the SDI program, I think we have got to keep all of this cost in mind as well. This is another dollar figure that has to be added to the Star Wars column. But if we are going to go forward—and I will conclude on this statement, Mr. Chairman.

If we are going to go forward with a heavy lift vehicle, I think it is extremely important that we not have this given to the Air Force along with the national aerospace plane and shut off both of the potential avenues for NASA to continue its leadership role in the exploration of space. And in addition to that, when you have got the expertise I have referred to, the people, the test stands, the experience, the tradition of technology development, I just think that it would be a serious mistake to not have NASA play the lead role in this program.

I appreciate my colleague's courtesy.

Senator RIEGLE. Secretary Aldridge, I think you wanted to respond. And maybe you do not, but if you do I want to give you the chance. And in responding, if you could indicate the part of the heavy lift capacity that is required for the projections of Star Wars versus other, that would be helpful.

Secretary ALDRIDGE. Mr. Chairman, as you know, projection of a SDI requirement is somewhat loose, because we don't know when such a capability will be required because we don't know yet if the technology is there to make the decision to proceed. But there are estimates of requirements of when an interim solution might be required. It is consistent with the requirements as Mr. Myers has stated for some support for a space station in the 1993, 1994 kind of time frame, the beginnings of, if we were going to build such a capability, the beginnings of that, but it is not just SDI. I mean, there is a general agreement through the Department of Defense that independent of Star Wars there is a requirement for a heavy lift vehicle of some type.

Senator RIEGLE. What is the split? That is what I am interested in. If you leave out the space station, what is the split on defense, Star Wars, non-Star Wars?

Secretary ALDRIDGE. All right, sir. The plan right now General Abrahamson wants to have an option to begin a deployment as early as 1993, 1994—he will not be any more specific than that—and a growth rate building up from that point on. If it was not for SDI it would be 1997. That was consistent with the STAS study that was completed, that late 1990s would be an appropriate time for the Department of Defense to have a heavy lifter.

Now, the question is, if you are going to have a heavy lifter we want to have it in a capacity that is very inexpensive to launch. It is our opinion in the opinion that we saw in the STAS study that new technologies, not just in boosters, but launch concepts, launch operational concepts, new approaches to making boosters fly cheaper without large standing armies and making the overall costs to launch a satellite much, much cheaper, and we felt the technology would permit us to get launch costs down by a factor of ten by the mid—the late 1990s, and that was the technology plan that was paid out for a heavy lifter.

Now, if General Abrahamson does in fact need an earlier capability then the approach that we were going to take was, can we take the ultimate technology for a low-cost heavy lifter and fly a variant of that earlier in time? I do not know the answer to that yet. We have now set up a study group out at space division in California to begin the process of studying can such a capability exist. It may not. The other approach to that is to start from where we are today with the shuttle and go to 1993, 1994 with a shuttle derived vehicle. That is another approach. But we knew that that was not the ultimate approach we would like to get to with a lower cost per flight, because that would use existing concepts which are very expensive.

Senator GORE. Would the Chairman yield briefly?

Senator RIEGLE. I will. Also with the indulgence of Senator Pressler. But I want to be sure I understand what you are saying. Even without Star Wars, you are saying by the late 1990s the Defense Department is saying its heavy lift needs for other defense activities——

Secretary ALDRIDGE. Yes, sir.

Senator RIEGLE [continuing]. Even if there is no Star Wars, you will be required to be in the heavy lift business by that time?

Secretary ALDRIDGE. Yes, sir. 1997, 1998 time frame.

Senator RIEGLE. But you are also saying if you are going to get there sooner—mean, if you are going to do Star Wars you have got to get there sooner.

Secretary ALDRIDGE. Yes, sir, and that is the money that is included within the Sar Wars supplemental in fiscal year 1987 to begin to accelerate that technology leading to an earlier time frame for that capability.

Senator RIEGLE. Senator Gore?

Senator GORE. No, go ahead.

Senator RIEGLE. I have finished.

Senator GORE. Well, it was my understanding—I was going to volunteer an answer to the question that you originally asked. It is my understanding that no matter what assumptions you make about the timing of the heavy lift program, that 90 percent plus of its use would be SDI related if the current SDI plan is issued. That is just the information that has been made available to me, that more than 90 percent of the heavy lift vehicle use would be SDI related.

Secretary ALDRIDGE. That is making the assumption that you would in fact deploy an SDI in the mid-1990s if you did not deploy an SDI in the mid-1990s obviously the time that you need a heavy lifter is later in time when the launch rate would be lower but the idea would be to use technology to get the launch cost down.

Senator RIEGLE. Give us a sense then of what kind of payloads there would be in the 1997, 1998 time frame that would require a heavy lift vehicle of 100,000 pounds per launch if you leave Star Wars out of it.

Secretary ALDRIDGE. Sir, it is not necessarily launching a single payload. You could be considering launching two payloads at a time of larger sizes. Unfortunately I cannot go into the details of some of those but there are concepts including improvements in survivability, improvements in command and control capabilities.

Senator RIEGLE. I guess I hear that you are saying you might batch a lot of things, and therefore you might need to send up that many pounds at once but I was really asking a different question. And that is, is there any single job that we envision out in that time frame that would require a payload lifts of that size?

Secretary ALDRIDGE. When we did the STAS study we combined the national requirements of DOD as well as NASA, and space station kinds of things were incorporated within the STAS study that led us to the heavy lifter in the late nineties.

Senator RIEGLE. That is very important. Senator Gore, I do not know if you heard that. But if I understand correctly you are saying that if you leave out SDI and you are looking at the late nineties, the load requirement you are going to have, you are including then NASA payloads.

Secretary **Aldridge**. That was a national requirement.

Senator **Riegle**. That is separate from my question. I was asking what the defense requirements are. I am trying to get a sense for what the defense requirements are, and it seems to me, that means leaving off the NASA requirements. If you add on their requirements to in a sense create a need, then you know you have really mixed two things together.

Secretary **Aldridge**. Mr. Chairman, we always looked at this as a national program. It is not a DOD program, not a NASA program. It is a national program, and that was the objective of STAS. Now, the difference was that at the time we did the study there was a clear definition by NASA that space station type things would be done by the shuttle, and I think there is some more information that says, well, if you had a heavy lifter earlier you could reduce the demands on the shuttle to meet some of those requirements, so it would be advantageous to us to have the thing earlier in time, but at that time it was in 1995.

Senator **Riegle**. Why would that not lead then to the point that Senator Gore was making earlier, and that is, if we decide not to go ahead with Star Wars and if part of the load feature out in the late nineties is NASA activity, why is it not just as logical then to build it and have it managed within NASA as within the Defense Department? Why could you not argue it almost with equal weight? It seems to me that part of the rationale is that you need your payload activity. Why can you not argue just as strongly the other way?

Secretary **Aldridge**. You can make an argument either way. I believe that the requirements will be dominated by the Department of Defense. I think that is where most of the requirements will come from, and we ought to be placed in the lead for doing that. NASA led on the shuttle. Why can we not lead on the follow-on to a heavy lifter? Or have NASA continue to focus on manned capabilities. We cannot do everything.

Senator **Riegle**. I guess where the gap comes is, if we do not do Star Wars and you are having a hard time identifying for me what the military heavy lift requirements are out in the late nineties, if we do not have the NASA loads grafted onto it—I guess I would like to get that blank filled in.

Secretary **Aldridge**. Let me make a comment. You are forcing us to get into a confrontation. We have not decided how we are going to manage this thing. And I do not want to get into a confrontation with NASA.

Senator **Riegle**. I do not think that is really our purpose. Our purpose is trying to decide where the best place is for the HLV to be. You just said a second ago the case could be made either way. We are trying to weigh the very same question.

Secretary **Aldridge**. When you put down what is the program which we do not know yet and we can identify where the technologies are, where the expertise lies to carry out those technologies, then we can identify what the management plan ought to be. I do not know what that is right now. I feel that the dominant requirements are being placed by the Department of Defense for those things, and therefore I believe we ought to pay for it and we ought to be in charge of it. We ought to utilize NASA expertise. On the other hand, I do not know what the configuration is. If we decided yes, the shuttle derived vehicle is the right evolutionary step and it is lower cost in the near term but is higher cost per launch but it is still better for us to do a shuttle derived, which could be the answer, I do not know that, then it may be that NASA ought to be in charge, and use our expertise to support them. I do not know those answers and until we define that it is difficult for me to sit and argue that we are better or NASA is better. In fact, I do not think we ought to even have that argument. It is a national program. We ought to figure out who is the most capable to lead it, and we will get on with it.

Senator RIEGLE. You wanted to make one other comment?

Senator GORE. I did, Mr. Chairman. I appreciate your indulgence and that of Senator Pressler. I wanted to fill in this gap that you referred to, because I have here some Air Force documents that have recently been unclassified that provide the answer to that question in connection with the program research and development announcement of the heavy lift launch vehicle design. They provided these graphs, which clearly show that without the deployment of SDI the military and NASA requirements up through 2010 are approximately .6 million kilograms of launch capacity. With SDI deployment they're above two million kilograms of launch capacity and in the text of this is this statement. They say the system should be capable of meeting the latest STAS approved normal growth requirements less planned shuttle and other expendable launch vehicle capability and potential Strategic Defense Initiative polar requirements of approximately 400,000 pounds per year in fiscal year 1993, one million pounds per year by the mid 1990s, and more than five million pounds per year by the late 1990s.

Now, a 2.25 million kilograms I guess is the same as five million pounds.

Secretary ALDRIDGE. That is close enough.

Senator GORE. That would be 2 million kilograms per year, so what you are talking about here is the fill-in for the blank. I will provide these if you want to see them, Mr. Secretary, but it clearly demonstrates that without the deployment of SDI in the next few decades then the heavy lift vehicle is really not needed.

Secretary ALDRIDGE. Senator, the kilograms you are talking about is about a million pounds a year. That is twice what we are flying now. That is twice the capacity of what we projected the shuttle to fly.

Senator GORE. But it does not exceed what the shuttle derived vehicle could give you.

Secretary ALDRIDGE. At a very high cost. If you could reduce the cost of the shuttle launch by a factor of ten, we will more than pay for the development cost of a heavy lifter and it would amortize over a fairly short period of time. That was the notion which we were assuming with twice the launch capacity and with a lower cost to flight by a factor of ten it would be worth it to us to develop and invest in the technologies for heavy lifter. That would in fact give you that lower cost per flight. If the cost per flight of the shuttle which we know of and the shuttle derived vehicle were roughly the same, and maybe you could reduce the cost, then you could not achieve that factor of ten reduction in cost and therefore the launch cost would be double what it is today, and that is too expensive.

Senator RIEGLE. This is a very useful discussion. Mr. Myers. Then I am going to call on Senator Pressler. Go ahead if you have a brief comment.

Mr. MYERS. The brief comment is that part of what is involved here is the issue of reliability. NASA has really driven reliability hard, all the way through the whole history of our space programs, Saturn 1B, nine vehicles, zero losses, the Saturn V, 13 launches with no losses, the Shuttle, one terrible disaster after 25 successful launches. The issue really to us is going to be a tradeoff of the potential of the terrific impact that occurs to our programs when we lose a vehicle. Look what has happened to our whole science program because of the loss of Challenger. Look what would happen if we had a Hubble Space Telescope on an expendable launch vehicle at 93 percent reliability and lost it. We must worry about high reliability in any of these future launch vehicles. The thing that can happen in the long haul is the application of advanced technology and advanced materials to a very high reliability vehicle of lower cost than we have today. I do not think I will ever say ten to one again. I did that at the time the shuttle was being developed. But the fact is you need to drive in that direction if you are going to do something in the 1993 time period. We just tend to think that you have got to look at it both ways, look at the technology of the 1997 time period and see if it can be applied to the 1993 time period and look from the shuttle forward to see what kind of device you get and that kind of reliability you get at that time. Cost and reliability. We have got to look at both of those in the study that we are doing jointly with the Air Force.

Senator RIEGLE. Senator Pressler.

Senator PRESSLER. Thank you. Following up on that, and some of my questions have been asked, but just to fill in, would you comment on what advantages that a shuttle derived HLF offer compared to an HLV that takes advantage of newer technologies and when could such a shuttle-derived HLV be available and for what cost could it be developed?

Mr. MYERS. We are going to have a continuing activity. That is the key question, Senator Pressler. The issue is if the requirement is like 1993, 1994, what kind of high reliability vehicle can you get in that time period? If you really have some more time, what kind of advanced technologies, advanced materials and capabilities could you bring into a new, clean sheet of paper vehicle to give us quick response, lower cost, easier integration of payloads, and all of the things that you can imagine can come out of the learning experiences of the Shuttle today? Now, on the other hand if I need something in 1993 and the elements are already there. The SSME engine is there. The tanks are there. The solid rockets are there. It is pretty obvious that you have got something that is going to be high reliability and available at an early time.

The other part isn't that obvious. The question of looking at an advanced vehicle and seeing what you can do to bring that technology back into the 1993 time period, that is what the study is all about, and we need to really put some strong emphasis on those issues that you bring up.

Senator PRESSLER. Now, concerning a shuttle derived HLV or an HLV that uses newer technologies, what are the considerations of early capability versus technological advancement?

Mr. MYERS. Well, it is probably finally going to boil down to requirements of time, because I think we are putting a lot of emphasis in what the technologies are that can reduce the cost of launch. We all have the same problem. Launch costs are too high both for the Air Force and for NASA, and we have got to reach for ways to reduce it. The heavy lift launch vehicle study, even though there hasn't been an awful lot of money put into it, has revealed some really interesting technological approaches to reducing the cost to launch.

The question we really don't have an answer to yet and the reason for the study that the Air Force and we are initiating is to get a better understanding of those tradeoffs. What technology can you get from a clean sheet of paper vehicle designed for the late nineties that you could pull back into the early nineties? On the other hand, what is the possibility of a shuttle derived vehicle evolving into a low-cost vehicle? We do not know those answers yet and we need to study them.

Senator PRESSLER. Secretary Aldridge, according to the Air Force announcement of its HLV design competition, that design effort should meet the national access to space requirements of commercial users. What assumptions have made, or what options are being considered concerning this reference to commercial user requirements of an HLV?

Secretary ALDRIDGE. I am not sure I understand the question. The commercial applications of a heavy lifter I do not believe have been factored into the design requirements. What we are looking for is all the users of space have been factored in, including the SDI to determine overall requirements, and what we are looking for is a concept for the government development of a heavy lifter. A commercial variant of a heavy lifter is probably beyond the ability for the commercial contractor to bear the brunt of it unless it was using derivatives of existing technology. That is a possibility that we could go through some existing technology getting to the ultimate vehicle, but I don't believe the contractor can spend—afford the risk of the huge research and development costs necessary to get there.

Senator PRESSLER. Secretary Aldridge, to what extent do you support the commercial procurement of ELVs as opposed to the procurement of ELVs through the conventional government procurement process?

Secretary ALDRIDGE. We have to have both. There are expendable launch vehicles that are not applicable for commercial application. Titan IV is one of those. We fully supported that. Another vehicle that can be used to support DOD payloads but the production of which makes a commercial variant viable is the Delta II. I am probably one of the strongest advocates of a commercial ELV industry as you can find and have been pushing that for the last three years.

Senator **Pressler**. Following up on that the report of the Commercial Space Transportation Advisory Committee recommends that the Air Force should attempt to make the commercial use of its ELV launch ranges consistent with the commercial viability of ELVs. What specific actions have you taken to see that the commercial use of air force launch ranges is, in fact, consistent with the commercial viability of ELVs?

Secretary **Aldridge**. We have made launch ranges available to commercial users at what I would call the incremental cost. We will pay the majority of the launch range operations, and if there are any unique costs that would be additive to that for commercial launches the commercial user would only have to pay that incremental cost. For example, if we had to hire another security guard because of a commercial application they would only have to pay for that additional guard, not all the other guards that would be associated therewith. That particular committee was somewhat critical of a draft of a contract that we would propose to the commercial users. It was a draft. It was sent out for comment. We got some comments back. We have now made significant revisions to that draft. It is my understanding that almost all the issues have now been resolved except for one problem, and that is how much is the government going to provide in insurance in case of a catastrophic failure of a launch such as a booster falling on a major city where a contractor could not afford to buy the insurance for that event.

Can we get around having some type of shared responsibility, and my understanding is, we are almost in agreement on that last issue. So I think we are almost there in regard to ability for commercial users to use government facilities, tooling and so forth.

Senator **Pressler**. This is my last question. The COMSTAC report raised the concern that the Air Force ELV commercialization agreement exposed commercial ELV operators to an almost unreasonable risk. I know you covered that, but what is the position of the Air Force on the assumption of liability for its actions on Air Force ranges? The COMSTAT report also states that the agreement subjects the user to undefined and almost uncontrollable costs. What specifications are you taking to define and control the costs for which the commercial user would be responsible?

Secretary **Aldridge**. Well, we basically have understood better what the problem is in the draft of the model contract which has been reflective of those concerns in the contract. I think the only remaining issue I am aware of is this liability for catastrophic failure, and in that case the guidance that we have provided assuming it is legal, to our general counsels is that the government will be liable for those areas which it has responsibility for, and one of those is range safety. And if there is anything that happens as a result of after launch in which the range safety problem fails and there is a catastrophic failure, the government should be liable for that if there is anything that occurs during which the contractor is responsible, such as the booster blows up on the pad and destroys the pad, the contractor should be responsible for that and they have agreed with that particular notion.

Senator **Pressler**. Thank you very much.

Senator RIEGLE. Secretary Aldridge and Mr. Myers, I have about three things I want to touch on. You have been very patient, and I will try to go through them as rapidly as I can.

Secretary Aldridge, I admire very much the leadership that you are giving in the Defense Department in this area. I mean, you seem to me to be the person who ought to be in charge of the job you have, and you are moving it along. I am very much impressed with the fact that you are mission minded as you have to be. There are missions that are set out for your job, you have to get them done, and you look to me like the sort of guy who will burn the midnight oil to figure out how it can be done. That is the way it should be.

Let me ask you to respond to this observation that I might make about NASA. It appears to me that NASA today is struggling. It has a new team, and everybody is working hard, and I think they are doing everything that they can do to move things ahead, but there are a lot of things that would point to that.

I think the differential budget relationships and the projections show that. The fact that in terms of future missions as we talked about a while ago, the heavy lift vehicle and the aerospace plane look like things that the Defense Department would very much like to do for doing rather than have those primarily be jobs that NASA would do.

NASA is left basically with its principal mission for the foreseeable future, the space station, but to get to the space station they have to get the Shuttle built to replace the one that has been lost, and the space station keeps sliding. It keeps sliding further out in time, plus it gets more ambiguous because there are difficulties now even with working out the international agreements partly because the Defense people are in the act and have some concerns about it. That seems to be creating some complications even with respect to the space station agreements with international consortium.

In addition to that, NASA is told that they have to get out of the commercial launch business and in effect are out of the commercial launch business.

There is the Presidental national security decision directive number 254 issued by the President in December of 1986 that says, "NASA will not maintain an ELV adjunct to the STS. If there is a need for additional mass capacity for government launches, then NASA is authorized to contract for the necessary ELV launch services." That is not completely clear to me.

I put all this together and I get out and talk to people in the scientific community as well who are very much interested in scientific probes and research probes that have been under way in design for some period of time at the University of Michigan and other places. The whole space science area is also under considerable pressure partly because there are fewer launch slots and because of all the difficulties that we know.

Add it all up, and the picture is that even though you have an awful lot of very dedicated people working very hard in NASA, the picture does not look nearly as bright when you take all these things into account as it does over on the military side with the space program, where it is mission oriented. There are very exotic things like the Star Wars program that are there and offer some potential for some major scale things to happen, major leaps in technology being planned to try to go the space place, and the intermediate technology before that.

I guess I would ask you as a person over here in the shop where everything seems to be moving at high speed, when you look back over here on the NASA side, and I have not mentioned all of the items but all the ones I have mentioned are real and facts, how does one escape the conclusion that NASA is really sort of getting clipped in a fairly tight straitjacket here from all these different things and that we are really seeing a major shift in space emphasis by this country for a variety of reasons in the direction of military or defense-oriented activities and a way from the civilian agency activities which have been the things that the country has thought about and most associated with, going all the way back to John Glenn's flight 25 years ago?

Are we not witnessing a pretty fundamental shift here, and what are your thoughts on it?

Secretary ALDRIDGE. I cannot argue with many of the things you said. A question I would have is what you want us to give up in the Department of Defense to shift over, and I guess the issue of the heavy lifter is one of those areas that might be moved over, but somebody has to be in charge.

My problem with all of this, and Dale Myers can comment on this, is that I look upon NASA as a research and development agency. That is their fundamental thing, push technology. The Department of Defense also has research and development, but it also has operations. We have a day-to-day operational thing.

I saw the heavy lifter, and if there is an SDI it certainly will be that the heavy lift vehicle is an operational system. It is not a research and development project. Research and development should be shared. That was our intent, but somebody, one person, has to be in charge.

If it is ultimately an operational system, which we want it to be, that does the routine operations and not a research and development activity, then it ought to be in the organization that is going to do the operations. I felt very strongly that that was the Air Force that ought to take over that responsibility because that is where it is going to be operated from for primarily Department of Defense reasons.

One could argue, well, okay, have NASA do the development and then turn it over, but that is not an efficient way to do business. An efficient way to do business is give it to the person who is ultimately in charge and let him go do it using all the expertise in the world they can find, and I would say a great percentage of that will come from NASA and the contractors because it is the contractor who ultimately builds the system. It is not the civil servants that are in the Air Force or the civil servants that are in NASA. It is the contractors who do it.

That is where I was coming from. I felt strongly that that was the appropriate place for it to be; but yes, the Department of Defense is growing in its use of space. It is logical. A lot of the technology that was developed with NASA is being allocated to the Air

Force, and a lot of the stuff that the Air Force is doing has been allocated back to NASA. There is a sharing of technology.

Even in the booster area, the STAS effort did in fact establish as a day-to-day kind of operation an ongoing integration of the technology work on boosters and launch vehicles, including avionics and that type of thing.

I would like to think that for the future launch business that it ought to be a national type program, but some one person has to be in charge, and we have to figure out who the best person is, but I do not argue with so many of the comments that you made.

Senator **Riegle**. Well, I am trying to understand it. I am trying to illuminate it for my own mind and for others because I think some very dramatic shifts are occuring here, and part of our job is to try to understand those and make some sense out of them.

You used the word "operations." When I try to transfer the word "operations" going backward in time, it seems to me that the civilian space agency from the beginning was involved in a whole series of kinds of operations, if you will, in terms of getting people into space, the whole moon probe, if you will. We have not set up an ongoing operation, a moon base or such as that, but it was certainly a very elaborate operational exercise over a long period of time to do that.

Certainly the Shuttle program is that. The Shuttle program aiming at building the space station, I would think that would meet sort of an ongoing operational definition because the idea is to have a space station that stays up there and people work in it on an ongoing basis and so forth.

I think you could also say that launch activity over a period of years was an operational function. I think the scientific and research activities were an operational function.

It seems to me, however, that in the sense of operations or missions that we seem to be reaching a crossover point there as well. The crossover point on budget is very easy to see. It seems to me that we are getting to a crossover point on mission and perhaps vitality and perhaps purpose, and I think you may have stated it; that is, I think there may be an emerging view that says that NASA ought to primarily be a research and experimental type operation and that increasingly the effort to go and make big things happen perhaps ought to be over in the defense area, not just for defense requirements but even to pick up residual nondefense items that may have been NASA functions in the past but can get packaged in and used and taken care of in terms of defense capabilty in the future.

If that is where we are going, I think it is important that we understand that. We have reached a crossover point in terms of missions or substantial new initiatives or major research and development efforts. It seems to me to be very substantial technological efforts are needed to design and really make some huge breakthroughs in systems.

If we are now going to move our thinking over to the point that those are really functions which ought to be within the defense establishment, within the Air Force presumably, carried out there, I think we can decide to do that, but it seems to me that that is something of a change from where we have been. If you look at the future versus the last 25 years, I think that involves a crossover point in terms of leaving NASA the operational agency, and in effect, with the possible exception of the space station, which now has a lot of question marks on it anyway, that that role would in fact move on over to the Defense Department.

Would you take sharp issue with that?

Secretary **Aldridge**. I cannot because I do not know exactly. I cannot pick up a specific project that you would move over.

I think we ought to separate the military space program and the civil space program. I think we are trying to merge those two close together and this is not in the best interest because they have different functions, they have different priorities and so forth.

I would take exception to the comment about the operational aspects of the civilian side. I think when you launch an Apollo, there is a mission. It is an operation, but it is in fact associated with research and development for a particular goal.

When you launch a DOD satellite, it is because you are doing something in the operational sense of putting a capability, achieving a mission in space. There is a priority associated with that. There is a need to launch on a particular day for a particular reason, and it is being used in an operational sense for military operations, and it is repetitive. You are going to launch one a year and we are going to continue to do that, or when you add all the DOD launches, you are launching four or five or 20 per year.

Senator **Riegle**. It could be like weather satellites. It could be communication satellites launched by NASA, things that go up and there and stay up there and work for years.

Mr. **Myers**. Like one of our planetary missions that have to meet a certain window. That is an operation.

Secretary **Aldridge**. But it is a repetitive type of thing where you are doing a single mission. The mission is putting that satellite for an operational sense in orbit and doing it repetitively, over and over again. It is not putting a man in space to do a series of experiments which are needed, there is no doubt about that, but it is not the same kind of thing. The focus is somewhat different.

I believe that when you get into launching heavy lifters or aerospace planes, that is a little bit different because I do not know what an aerospace plane is, and there could be variants of it. It could be a complete commercial airliner, it could be a space booster, it could be a military thing.

I think in the operational sense it is a little bit different. The mission focus is different.

Mr. **Myers**. Mr. Chairman, may I make a comment here?

Senator **Riegle**. By all means. I was going to call on you for your response.

Mr. **Myers**. Thank you. NASA has an operations role. The Shuttle certainly is an operational role even though we tended to drive it too hard in that direction, and we now talk about it not being fully operational. It certainly has a repeat launch requirement. It has all these issues, getting launches off on a certain date to give a certain window for a planetary mission, for example. The Space Station is going to be a long term operational activity.

We, in fact, are so dramatically impressed by the long-term operations requirements of NASA that we have reorganized NASA to set up an operations planning organization to look at the issues of operations planning for the future. We are going to have a long-time involvement in operations, and I think that the issue of who is going to be the leader in this activity is something that is open for a lot more discussion between NASA and the Air Force.

We have a study that needs to be done to define what it is we are talking about, and we have a job to do to recognize the national capabilities that are here to be applied to a heavy lift launch vehicle. Those things are going to take some time. As I mentioned earlier, Secretary Aldridge has asked me for our comments on that, and we are in the process of putting together our comments for response. We have a lot of work to do in this activity.

I think it is important for you to know that the STAS study was about a $5 million study to four contractors. It is not a very deep and extensive study, and we do have quite a lot more to do to really understand what the requirements are on the side of NASA, what the requirements are on the side of the Air Force, and what the requirements are for SDI. How does this all reflect finally into what launch dates you need and what sort of vehicle comes out of that. I do not really think we can say now whether it is a Shuttle-derived vehicle or this advanced high technology vehicle that we are looking for.

Senator Riegle. I appreciate what you both have said and the candor and the expertise from which you speak in putting it forward. If you put what you both said side by side, I think they are quite different messages. That is not to say they are in total conflict with one another or that they fit together perfectly, but I hear two quite different visions there, if you will, as to the future, and I think there is this ambiguity. I think there is this tension, and I think it is confused as to how we are going to sort these roles out. I do not know that we are getting much of a debate on that at least out in the open.

Now, there are other things that I worry about. Talent in this area is very scarce as you know when you try to go out and hire for what you can spend, the engineering talent and the rocket talent and so forth. I have been very impressed that the people have been willing to come in and work at NASA now under tough conditions. I think we have been extraordinarily fortunate in getting some of the best talent in this country, some of it seated in this room, in addition to yourselves, out in other seats in the room. The whole country is appreciative of that.

Nevertheless, there are limits as to how many people there are out there that we can get, and so the whole question of how we are going to sort out this scarce talent is also a matter of concern to me. Senator Bentsen feels very strongly about the whole question of whether we are doing enough to sort of produce talent so that we can handle even the thing that we now see in front of us.

I am frank to say to you, Secretary Aldridge, I am concerned about the technology transfer. I am concerned when we get into the defense area where a lot of things are classified I am not sure that we get as readily the accessibility to what we are learning out and disseminated broadly into the nongovernment sector and through the university community and other places as readily as we do when we are dealing with information that is in a civilian agency.

I am not trying to put that in black and white form, but I think particularly when we get into something as exotic as SDI, the whole business of how rapidly we get the spinoffs in terms of whatever the nonmilitary dollar value applications are to the civilian population which is of great interest and great importance to the country, I think it is just different. So, you know, I think that is just one thing that has to go into the equation when we decide who is going to do what in terms of where it ends up being because I think there are some differences there.

I think the country needs to get this issue focused and framed, and so I think it is very important that you both be here. I respect the work that both of you are doing, and I know you are endeavoring in every way you can to work together, but it seems to me the inherent tensions that are growing here, including the budget tension—Senator Hollings made the point earlier that maybe we need to raise more money so we can do more things, but until such time as we do, the exercise we are in right now is to figure out how we can do fewer things because we are having to squeeze down the spending.

So when it gets squeezed down, does it get squeezed out of your budget, or does it get squeezed out of his budget? Some of this is going to have to be a tradeoff between the two of you. I do not think it is clear to us yet just exactly how that is to be done.

We do have one other witness that is due to be here today, and I want to thank you both for your work. We appreciate the fact that you are here, and hopefully together we will continue to map out our directions for the future.

Thank you very much.

Secretary Aldridge. Thank you, Mr. Chairman.

Mr. Myers. Thank you, Mr. Chairman.

Senator Riegle. Mr. Stadd, let us welcome you to the committee here.

Let me ask everyone who is going to stay to see if they can find a seat.

Mr. Stadd, we are pleased to have you here as our final witness today. You have had the opportunity to hear everything else that has been said today, so you may have comments that you wish to make that relate to other topics that we have spoken about, but we would be pleased to hear your comments at this time.

STATEMENT OF COURTNEY STADD, DIRECTOR, OFFICE OF COMMERCIAL SPACE TRANSPORTATION, DEPARTMENT OF TRANSPORTATION

Mr. Stadd. Thank you, Mr. Chairman. Thank you very much. There is indeed an advantage to be able to sit at this table rather than be back there and have some perspectives to share with you, so I appreciate the opportunity.

I especially appreciate the opportunity to make my maiden appearance here on the Hill and to report to you and your colleagues on the status of the commercial space technology initiative.

To date, Mr. Chairman, domestic ELV manufacturers have signed over a dozen reservation agreements with deposits with satellite customers. That was referred to earlier, and I am pleased to announce that Martin-Marietta in particular has submitted mission review requests for two payload customers and that we expect to receive a third request from another large firm momentarily.

A young entrepreneurial company by the name of American Rocket Company, I have just been informed, has initiated the licensing request for a test launch to be conducted later this year.

I think it is fair to say, Mr. Chairman, that the response of America's private sector has sent a clear signal to our foreign competitors. We are not standing idly by while rocket technology we pioneered is taken away just at the very moment its transfer to industry becomes profitable to the American economy.

If I may digress for a second, Senator Bentsen referred to earlier that he hoped by the end of the year that we all may come back to you and report positive results in this area. I suspect that you will be a lot more impatient than that, and I intend to be able to report more positive results in a matter of months. I would like to explain what I think are the outstanding barriers to get to that point.

In the past several years, the President and Congress have been committed to creating an institutional framework to enable the private sector to provide launch capacity on a commercial basis, capacity that has become more precious in the wake of the Challenger accident to say the least.

It was this commitment that led the President and Congress to direct the U.S. Government, and DOT in particular, to encourage private sector launches by expediting the approval process for commercial launch activities, among other initiatives.

Our legislative charter sets DOT apart from other agencies involved in space. This is often lost sight of. Unlike NASA, Air Force or NOAH, for example, we are not in the business of building, launching or contracting for launch vehicles or services. Rather, as with other industries DOT regulates, we are mandated to develop effective policies and guidance that allow private providers of transportation to thrive while insuring that the public safety is protected.

Under Secretary Dole's leadership, DOT is helping to create conditions necessary to enable our U.S. private launch industry to be competitive, and we are doing so in consultation with the broad cross-section of the space industry, launch vehicle manufacturers, satellite owners and operators in the insurance and financial communities.

In August after serious study by cabinet level working groups—you notice I avoided the qualification, "lengthy"—the President announced his decision to take the Shuttle out of competition with private launch companies for routine commercial satellites.

His presidential directive was based on a plan to provide affordable access to national range facilities, accelerate commercialization agreements between government and industry, referred to earlier by Mr. Myers, and include commercial adaptability as a factor in evaluating the medium launch vehicle proposals and initiate an interagency effort to define the desirability and scope of international negotiations concerning fair competition for launch services.

Most recently, the President included the commercial ELV industry in the commercial initiative announced in the State of the Union address. Establishment of an effective regulatory program is well under way. Interim licensing policies and procedures developed to implement the Commercial Space Launch Act were published last year and will be published in revised final form this spring.

Also, we have been working closely with other agencies to resolve operational issues that have stood in the way of final commercialization and range use agreements. These agreements are motivating the industry and government to focus on and resolve a number of fundamental issues: the changed role of government and its implications for the allocation of risk, the cost to commercial operators of purchasing services and facilities, environmental issues, and the overall issues that characterize any commercial enterprise.

Because access to existing launch facilities is so critical to the industry, we are working closely with the Air Force to ensure that the range use agreements are responsive to commercial launch industry needs and requirements. I asked our Commercial Space Transportation Advisory Committee to review a draft of the Air Force's model agreement covering use of these range facilities. A comprehensive analysis of the draft was prepared and submitted to both Secretary Dole and Secretary Aldridge.

The report concluded, as was referred to earlier, that the draft was "overprotective of the government's interests and should be rewritten with greater consideration to its impact on commercial enterprise."

In particular, it pointed to liability provisions that would expose the industry to almost unlimited risks, uncontrollable costs, burdensome billing procedures, excessive demands for data disclosure, monitor and control responsibilities beyond those really required for assuring public safety.

Secretary Aldridge has demonstrated strong leadership in assuring that the findings of the COMSTAC report are fully considered in the range use agreement. One example of this leadership was a symposium held in December at Patrick Air Force Base. The symposium I believe was successful in opening up a very constructive dialogue among those most affected by the commercial launch industry.

Our view is that the most important aspect of DOT's charter is assuring that no aspect of commercial launch activity poses unreasonable safety risks to the public. In developing effective safety requirements, DOT conducts analyses of the same scope and depth as its research regarding other forms of transportation.

It is this effort that drives our fiscal year 1988 budget request. This budget anticipates the addition of two technical staff positions to assist in the development of a research program and the evaluation of commercial launch license applications, in addition to a request for $4 million to conduct the regulatory research itself.

Let me quickly add that, in light of the rapidly emerging commercial industry, the Secretary has directed me to assess the resources currently available to the Office of Commercial Space Transportation and to develop and execute a plan to ensure that we are able to respond effectively and, I emphasize, in a timely fashion in carrying out our regulatory responsibilities.

That plan is under development, but I do expect to be in a position to share it with the committee in the very near future.

Our research program will provide appropriate safety standards and criteria for commercial launch operators. At present we see a need to develop a data base of information specifically applicable to regulating a commercial space launch industry.

We are particularly sensitive to the need to recognize the commercial importance of this type of information to the business community, in addition to its significance to the government, of course.

American firms have the resources and capabilities to be successful competitors in the international market. By fulfilling our commitment to implement the President's policy and the provisions of the Commercial Space Launch Act as laid out by Congress, we believe we can create the conditions necessary to enable U.S. companies to compete in the international market and reduce the backlog of satellites awaiting launch.

Well, after nearly four years of effort, a policy framework is in place that establishes the basis for successful commercialization of space transportation. With continued Congressional support, we will be able to put domestic ELV's to work in an increasingly competitive international marketplace. The result, Mr. Chairman, I believe, will be a stronger, more resilient American space transportation capability.

Thank you, sir.

Senator RIEGLE. Thank you for your remarks and your testimony today.

Is there a foreign or international launch capability that is not getting direct help from a government in that country?

Mr. STADD. I am not aware of one. I think that, going through the stable of foreign competitors, all of them are getting some level of assistance, yes.

Senator RIEGLE. It is pretty substantial. Are these really, as much as anything, national commitments of governments and nations, as opposed to private sector sort of risk money efforts?

Mr. STADD. Well, the most major competitor, the French Arianespace Corporation, is by French society standards, their approximation of what we call a private sector initiative. It is a quasi-public corporation.

Senator RIEGLE. How about by American standards?

Mr. STADD. By American standards—in some cases you are comparing apples and oranges. But I would say by American standards that there is probably—I would say by American standards it probably would pass muster as a commercial venture in terms of the level of government support.

Senator RIEGLE. If that is so, is that the same—would that mean that we could anticipate that a commercial launch industry could get going in this country without direct government help?

Mr. STADD. Yes. Let me explain. I notice the skepticism, so let me pursue that for a moment. In the area of Arianespace, there has been every effort to ensure that that effort is on a self-sustaining basis. True that in the case of the range support down at Korov there is apparently some level of assistance provided by the government. But my understanding is that that is based on some sort of reimbursement policy.

But as I say, it is very difficult to make a comparison between these different systems and what our system is.

[The following information was subsequently received for the record:]

U.S. Department of
Transportation
Office of the Secretary
of Transportation

400 Seventh St., S.W.
Washington, D.C. 20590

APR 8 1987

The Honorable Donald W. Riegle, Jr.
Chairman, Subcommittee on Science,
Technology, and Space
Committee on Commerce, Science, and
Transportation
United States Senate
Washington, D.C. 20510

Dear Senator Riegle:

Based on my review of the transcript of my hearing before your Committee on March 5, 1987, I would like to clarify my comments regarding Arianespace.

What I was addressing was my view that Arianespace has many characteristics of a commercial marketing agent. At the same time, however, the scope and level of governmental assistance provided by the member states of the European Space Agency to Arianespace may not be entirely consistent with the traditional concept of a U.S. commercial enterprise. It is well known that Arianespace has benefited from two-tier pricing; use of facilities, services, and personnel at less than full cost; availability of insurance coverage, sometimes at lower rates; export financing terms and rates; hardware and equipment at less than acquisition cost or market value; ongoing vehicle R&D; and malfunction investigations and design changes. Arianespace has also benefited from its bankruptcy-proof relationship with ESA member states; favorable foreign exchange and interest rates; government and supplier ownership of shares in Arianespace; and a protected European market.

Despite these factors, I stand by my remarks that the U.S. commercial launch industry can compete against Arianespace and other foreign launch providers for the following reasons:

- Long histories of unsurpassed mission and schedule reliability of Atlas, Delta, and Titan vehicles produced and launched by General Dynamics, McDonnell Douglas, and Martin Marietta, respectively, for the U.S. Government;
- Competitive pressures to launch successfully, to improve performance, and/or to reduce costs;
- In at least two cases (Martin Marietta and McDonnell Douglas), economies of scale resulting from production and launch of expendable launch vehicles for the Air Force;
- European preferences to fund cutting-edge technological research rather than to expand production and launch rates for existing technology; and
- The decline of the U.S. dollar in foreign exchange markets, which reduces Arianespace's capability to offer bargain-basement prices.

The U.S. Government is considering whether and, if so, how to negotiate international rules concerning commercial space launch services. The Office of the U.S. Trade Representative chairs an interagency committee to review trade-related aspects of government policies affecting such services. The committee is assessing the views of launch service providers and users on this matter.

I am convinced that U.S. commercial launch providers now have a timely opportunity to establish themselves in the western world's space launch market, while NASA attempts to fly off the backlog of shuttle-unique payloads and while Ariane is supply-constrained.

I appreciate the opportunity to expand on my views concerning U.S. competitiveness in space launches. I look forward to working with you and the Committee on means to advance the U.S. Government's policy to promote, facilitate, and encourage commercialization of launch vehicles.

Sincerely,

Courtney A. Stadd

Courtney A. Stadd, Director
Commercial Space Transportation

Senator **Riegle**. My concern is this. You know, it is one thing to say that a commercial industry can spring up in this country without government support in competition against foreign suppliers, who in my view do get very substantial government support. But it sounded to me as if you said that.

Mr. **Stadd**. No, no. Let me pursue that. There are many factors that make a commercial launch firm competitive. People have tended to focus simply on price, but as you know in the business world price is often less significant than the terms of financing, than the schedule of availability and reliability factors.

The satellite customer base is not in the business of obtaining insurance. They are in the business of putting satellites in orbit to receive revenue. With that in mind, it seems to me the American launch systems, which have benefited from literally hundreds of launches over the past couple of decades, stand very well when you compare them to the French that have had a fraction of those launches, when you compare it to the new Chinese Long March III, which is a newcomer to the field. They have had three launches, one failure.

When you compare it to the other systems that are being developed, by the Japanese for example, they are all at the beginning of the learning curve.

And those non-price factors, if you will, in terms of reliability and so forth, are really crucial to making our systems competitive.

Let me add one more thing, sir——

Senator **Riegle**. Well, before you do let me say this. We talk about that as if we are ready to make private sector launches next week or next month, and we are not. We are quite some distance away, and that time period between now and then is a time period where foreigners also have the opportunity to refine their capacity, their technology, and so forth.

Just on that point, if you were to pick a date in the future with some degree of confidence as to when you think the first commercial private sector launch is apt to go up in the United States, what would that date be?

Mr. **Stadd**. Well, with the caveat that these things are subject to change, I believe we could see the first commercial launch in 1989.

Senator **Riegle**. When in 1989? Mid-1989?

Mr. **Stadd**. Mid to late 1989, that is correct.

Senator **Riegle**. You say we could. Is that your best——

Mr. **Stadd**. Best.

Senator **Riegle**. What would you predict? What is your prediction? If that is the most optimistic, do you think that is the most likely or are you talking about 1990, or when are we talking about?

Mr. **Stadd**. No, no, I think that is likely. I think I have got to quickly add that when we talked earlier about government support for the other international systems, we still have a role here inside the Beltway in Washington to provide the type of environment that the American launch systems need.

Some of that has been alluded to earlier. Let us begin with range use agreements. Those are the ones that characterize the terms and conditions.

Senator RIEGLE. It seems to me those are tough, but that is the easy part. I mean, we can work those things out. How about insurance?

Mr. STADD. If I may just stay on that for a second, Secretary Aldridge made a very significant point earlier. How we price the use of those facilities in terms of how we define the direct cost of those facilities is fundamental to the ability of these companies from a commercial standpoint to plan.

There still are uncertain costs. We also have agreements that we have to arrive at with the tooling and equipment with these firms, and NASA has been moving forward to come in closure with these contractors, but we still have to finalize those agreements.

And finally, we have to come to some understanding of, as I referred to in my testimony, what the costs will be for purchase of services, support services at the ranges. The onus, the monkey, is still on our back. It is still on the Air Force, still on NASA, and to whatever extent we can fulfill our mandate to be a facilitator, to help bring these parties to closure in a matter of a few weeks.

Let me tell you that the launch industry has been coming to us and, if I may digress for a moment, it is helpful to see engineers and business people now coming to the office rather than, with all due respect to my lobbyist friends, rather than lobbyists.

So that is an indication, I think, that the rubber has in fact hit the road, that they are coming in saying: Look, the customers are coming to us and they are asking for firm quotes; in some cases we have been able to get away with the conditional reservation agreement with deposits, but we need firm quotes.

To do that, the government has to finalize these agreements that I referred to earlier, Mr. Chairman. And I think that is probably the most significant proactive step that we can take to create the environment necessary.

Senator RIEGLE. Where do you stand in terms of discussion as to insurance?

Mr. STADD. Yes, sir. Well, we started out, as I think Senator Pressler referred to earlier, with the first draft of the model agreement referring to holding harmless the government in all instances—which is commercially untenable, because that basically means you bet your company every time.

Progress has been made on that front. With the support of the Justice Department, we are now working with the Air Force to do a shared risk concept. Let me explain that a bit.

In that situation, the private sector would be responsible for the exposure that—whatever damage it causes, it would be responsible for. In that case the government in turn would be liable to whatever damage it is culpable for.

And then we would set some level of insurance. In the case of a third party, for example, we would set a level that we felt was commensurate with the safety standards and so forth and the history of the given system. And in the event of some sort of accident that exceeded that level, we then would negotiate to recover damages from the insurance carrier.

By the way, there is ample precedent and model for that in the aviation industry.

Senator RIEGLE. I wonder what those rates are going to look like, in light of our recent history in getting a new entity off the ground. I have a feeling that may prove to be a real problem.

Mr. STADD. Let me pursue that for a bit and amplify on insurance. There is a tendency in the discussion on insurance to treat it as, if you will, one ball of wax. And in fact, there are different types of coverages, different types of insurances.

Through our Act in Section 16, we have responsibility for the third party, helping to establish levels for that. Section 15 also gives us discretionary authority to work to negotiate coverage for a second party, damages at the facility.

Now, in reference to your point about new entrants, a moment on that. We are talking, at least in the near term, about an industry that is made up of the very same corporate entities and players that have been the backbone of the American launch industry these past 30 some odd years. These are people who are well accustomed to the reliability standards, quality control, and so forth that have been developed over the years.

The insurance industry has told us that they are very comfortable working with these entities and feel that they can work out attractive terms. In the case of insurance capacity, we really have not had the chance since the accident and the French accident to get a very good calibration of what the capacity is. We will know more in a few weeks as the insurance coverage for Palapa and the AUSSAT and EUTELSAT is sought.

But we have recently from the underwriting community heard that the underwriting capacity is up around $100, $120 million. In that context, let me also say that I think there has been an awful lot of naive capacity in the market for a lot of years, and if there is any silver lining to our experiences over the past year it is that there are a lot more sophisticated people and sophisticated understanding, I think, in the insurance field.

And again, our feeling is that there can be competitive rates.

Senator RIEGLE. Let me ask you this. This subcommittee has been approached by some of the commercial firms who say that if they are going to do this and get off the ground they are going to have to have some government business going along for the ride. Would you agree with that?

Mr. STADD. I think there is ample commercial opportunity to sustain the industry.

Senator RIEGLE. Without government payloads?

Mr. STADD. Without government payloads.

Senator RIEGLE. From the beginning?

Mr. STADD. From the beginning. I am not going to sit here and prejudge how many companies I am talking about and exactly what the magnitude of the market is required to sustain the industry. But I do feel that, just looking at the domestic and international part of the market, that there is sufficient basis for this.

Senator RIEGLE. Let me ask you this. With respect to your budget request for this year, the $4.55 million for fiscal year 1988, there was not a lot of detail as to how you intend to spend that money. Can you tell us where the principal focus of effort will be and whether you see the program expanding in any significant fashion in terms of your budget requirements over this next, say, five years?

Mr. STADD. Yes, sir. Let me preface by promising to submit to your committee's attention a more detailed breakdown of how that money will be allocated. But in general, the money will be devoted to research into safety standards.

We have several mandates. One is to be in a position to judge the safety of a given launch vehicle. So we have got to make ourselves smart, as we have in the railroad or auto industry, in the Department vis-a-vis an individual who comes in and says: I am launching from a given site. The bulk of that money will be going into establishing that type of data base.

There has been, by the way, as you know, a great deal of experience at the ranges over the past 30 years. But the information from the safety standpoint has not been aggregated, organized in a fashion to make it directly applicable to commercial operations. And, as I say, the bulk of the money would be going to do that.

We also have a further mandate, to be in a position to license completely a private launch range operation. We have been approached by a couple of groups recently who have expressed interest in this. I might add that the State of Hawaii, I understand, has expressed an interest in putting aside some acreage for a launch site.

We have to be in a position to effectively evaluate that type of proposition.

Senator RIEGLE. Do you have any plans this year to contract out for any studies or any services?

Mr. STADD. Yes, sir. We now have as of last week an announcement in the Commerce Business Daily for, I believe it is, a $1.9 million contract, letting it out hopefully with an RFP in March, this month, to begin the safety program evaluation for this year.

Senator RIEGLE. And is it the intent to—anything like that that you want to do in the way of outside services or studies, I assume those will all be published and made available?

Mr. STADD. That is correct. Today we have an analysis provided by the Research Triangle Institute regarding some particular safety aspects of operating at the ranges. We have also had an environmental report, which we would be quite happy—I do not know whether it has been made available to the committee, but I will see to it that it is. It is really a generic environmental assessment of what are the requirements in terms of launching from the ranges.

Senator RIEGLE. Well, you sound pretty optimistic. It sounds like you really see some potential here and you think things are moving.

Mr. STADD. I do, sir. I know that there has been a certain amount of—some people have accused some optimists in this area of handwaving in the last few years. But if I may be permitted to put this in perspective, Congress and the Administration have been exhorting and encouraging a private launch capability for a few years.

And I think there have been some people who have been wondering, where is it? And if I may, I think, to put that in perspective, beginning in 1983, the Administration and Congress, began to look in earnest at the issue. The President issued some directives.

In 1984, the Congress passed the Commercial Space Launch Act, which puts us in a position where I can tell you that we have institutionalized the capability to respond to commercial need. But it has only really been since August, when the capacity shortages and the budget constraints resulted in these changed payload priorities on the shuttle. And I think the American launch industry and the customer base are believers that they have got to look to the private sector for recourse.

And as Secretary Aldridge referred to earlier, that policy was only codified in December. So with those as parameters, I am very optimistic, because I have seen a great deal of activity just in the past few months.

As I say, we are now getting down to the nitty-gritty of operationalizing this, and I hope that in further discussions we will be looking at how we can fine-tune our support for this type of effort, rather than going back and debating the merits, because I do think we have got an industry in the making.

Senator RIEGLE. Very good. We may have some additional questions for you for the record, and we appreciate your testimony today.

Mr. STADD. Thank you very much.

Senator RIEGLE. The committee is adjourned.

[Whereupon, at 4:58 p.m., the subcommittee was adjourned.]

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR PRESSLER AND THE ANSWERS

AIR FORCE ELV COMMERCIALIZATION AGREEMENT

Question. As you mentioned in your statement, the Commercial Space Transportation Advisory Committee (COMSTAC) responded to the Air Force ELV Commercialization Agreement. This report was particularly critical of the Air Force's treatment of third party liability for damages to payload, personnel, and property.

Could you explain the nature of this criticism and any progress that has been made in resolving this issue?

What is the position of the Department of Justice on the allocation of risk between the commercial user and the government?

Answer. The bulk of the comments from the COMSTAC membership concerned the provisions governing liability for damage to persons or property involved in launch range operations—so-called "first party" or interparty liability—rather than third party liability. The latter term refers to injury to persons and property (U.S. and foreign) not involved in launch or range activities.

The COMSTAC members objected that the draft agreement exposed the commercial operator to "unreasonable, almost limitless risk." Specifically, the agreement asked U.S. industry to insure the Government for all damages caused by the launch companies as well as all damages caused by the Federal Government. Industry contended that the Air Force was asking industry not only to shoulder the burden of industry's risks attendant with commercial launch operations, but the Government's risks as range operator as well. Numerous comments suggested that the operator's exposure be limited, tying the operator's maximum liability to commercially available liability insurance, and limiting its exposure solely to damage for which it is responsible.

We believe the liability provisions of the model agreement should promote responsible sharing of the risks attending launch operations and are in the process of addressing the appropriate approach to this issue on an interagency basis. Based upon a review of risk allocation in the transportation modes, we approached the Department of Justice with a proposal to allocate risk for launch range activities in a manner similar to that used for other transportation industries: each party assumes responsibility for the damages it causes. The Department of Justice endorsed the concept of shared risk as a more reasonable approach for the U.S. Government to take. The Department of Transportation and the U.S. Air Force are working closely together to draft risk allocation provisions implementing this approach.

Question. Similarly, the COMSTAC report indicates that the current standard of third-party indemnification insurance that a user would have to purchase, $500 million, is about twice as much indemnification insurance as the user should be required to buy. Also, the Commercial Space Launch Act of 1984 permits the Secretary of DOT, in consultation with the Attorney General, to establish the amount of such insurance the user should buy.

What level of indemnification insurance has the Secretary of DOT established? What is the Air Force reaction to this insurance level?

Answer. The current standard for third-party liability insurance coverage (as established by NASA) is the "maximum insurance commercially available at a reasonable premium." In the past, the amount commercially available was $500 million for payloads using the space shuttle. However, the subject continues to be studied and the standard may be changed in the future if circumstances indicate that change is necessary.

The question confronting the Department of Transportation is what level of coverage is appropriate for commercial ELVs. Currently, the Department has a study underway to address the liability risks posed by commercial ELVs and identify the level necessary to adequately protect the U.S. Government's financial obligations under the outer space treaties.

No insurance levels have been officially established by the Department to date. In response to one company's request, a determination was made that, pending the results of the study, the Department would require this particular company to follow the traditional practice established by NASA. We have received no comment from the Air Force on this issue.

Question. Based on the COMSTAC response to the Air Force's ELV Commercialization Agreement, what other issues are you still having difficulty resolving? Which, if any of these issues are "show-stoppers" to the commercialization of ELVs?

Answer. Other issues that the Department and Air Force are working on include: scheduling priorities, safety, information disclosure, and dispute resolution. The Government is very interested in assuring that its agreement creates a healthy environment in which a competitive U.S. launch industry can develop without government subsidies. Several agencies are working cooperatively to resolve these issues. We do not believe that any of these issues are "show-stoppers."

Question. When do you expect to reach total agreement with the Air Force on an ELV Commercialization agreement, and how is the absence of a signed agreement affecting the U.S. commercial ELV industry?

Answer. We hope to have a completed final agreement ready for industry review soon. The absence of an agreement poses significant problems for the U.S. launch industry for two reasons. First, potential customers appear to be unwilling to sign launch contracts in the absence of signed range use agreements giving launch companies access to government facilities and services. Second, the absence of signed agreements means that launch companies are reluctant to draft proposals that include a fixed price component for the use of the ranges, creating a delay among satellite owners in signing final contracts.

NASA PROCUREMENT OF ELV SERVICES

Question. NASA is in the process of determining its needs for ELV services, and it is my understanding that you have been briefed on their procurement strategy. What is your assessment of this strategy—does NASA intend to purchase ELVs as part of an existing government contract, or does NASA intend to procure ELV services from the commercial ELV manufacturer?

Is this strategy consistent with the Administration's current policy on NASA's use of ELVs and with the Administration's policy on the commercialization of ELVs?

Answer. On February 13, 1987, NASA briefed DOT on the initial results of its mixed fleet study. This briefing consisted of: identification of payload requirements; the compatibility of the payloads with either shuttle or ELVs; the capability of various ELVs; the mixed fleet options identified by NASA and the estimated cost of each option; and conclusions and recommendations.

Although the study recommended that NASA implement a "high ELV" mixed fleet option, NASA indicated that the procurement strategy had not yet been addressed. It is our understanding that NASA is currently engaged in planning efforts designed to identify its requirements and options for procuring launch services consistent with its FY 1988 budget projections, whether by existing government contract or commercial procurement, as well as its preferred strategy.

It is our recommendation that wherever possible, purchase be made directly from the U.S. commercial ELV industry. We are, however, aware of the NASA/DOD quid pro quo, which would enable NASA to procure ELVs currently under contract to the DOD. We would take strong exception to any government procurement of ELVs that are no longer under contract for production to the DOD (e.g., Titan IIIs).

In the case of the Titan III, Martin Marietta has decided to offer this vehicle commercially, committing to undertake any investment associated with commercial development and sale. For the government to commit funding to procure the vehicle under a traditional government procurement would be extremely questionable. If NASA has a need for Titan IIIs and funds for their purchase, Administration policy authorizes NASA to contract for ELV launch services. NASA could, in this case, buy directly from the private sector since DOD is not contracting for Titan IIIs.

Question. Should NASA be permitted to procure ELVs as part of an existing government contract, rather than procure ELV services directly from the commerical ELV manufacturer, even if the procurement from the existing government contract resulted in significant savings over the procurement of services from the commercial ELV manufacturer? If not, Why?

Answer. There is no reason to believe the procurement under an existing government contract would result in significant savings. In most cases, where the ELV is under government contract and is also being marketed and sold in the commercial marketplace (e.g., Delta II), the price to the government was based on an amortization of costs over a total number of vehicles that include commercial sales. Therefore, the cost under contract or commercially should be approximately the same.

Although we support the concept of the proposed NASA/DOD quid pro quo to meet the current backlog of government mission needs, it remains to be shown that the cost of ELVs under this arrangement is significantly cheaper than commercial purchases made directly from the private sector. Total costs must be assessed, which include funding that actually changes hands between NASA and DOD, (e.g., proposed hardware costs), and also the cost of services provided. Services are indeed a cost even though it is an exchange in kind between NASA and DOD and no funds are transferred.

NASA/DOD "HANDSHAKE" AGREEMENT ON SHUTTLE/ELV HARDWARE

Question. As you are aware, NASA and DOD have a "handshake" agreement in which NASA will purchase ELV hardware from DOD, and DOD will purchase shuttle hardware from NASA. Is this agreement consistent with the comercialization of ELVs, or does it in any way conflict with or present problems for the commercialization of ELVs?

Answer. Given the very limited availability of launch capacity and the critical need for placing payloads in orbit as soon as possible, DOT supports the tentative agreement for puchasing ELVs that are currently under contract to the government. We do, however, hope that this will be a short-term solution to our payload requirements and that future requirements for NASA missions may be met through direct purchase of services from the U.S. commercial ELV industry. Such purchases will stimulate innovation as well as competition, and it is competition that ultimately reduces launch costs.

Question. Concerning this NASA/DOD "handshake" agreement, I understand that there is still some question as to whether the Titan III ELV will be considered a commercial ELV or a government ELV. In your opinion, what considerations should be taken into account in making this determination, and what are the implications of this determination for the U.S. commercial ELV industry?

Answer. Martin Marietta has publicly announced and is actively marketing the Titan III as a commercial vehicle. The Titan III is no longer being produced for the DOD. Further, the president's U.S. Space Launch Strategy states that NASA will not maintain an ELV adjunct to the Space Transportation System (STS); procurement for Titan III could be interpreted as a de facto adjunct if the only reason for the procurement was to meet NASA needs.

MEDIUM LAUNCH VEHICLE (MLV)

Question. The Air Force recently awarded to McDonnell Douglas the contract to develop Medium Launch Vehicles (MLVs). Since the beginning of this MLV competition, the Air Force had indicated that one condition of the MLV contract award would be that is should permit a transition of that vehicle to a commercial variant.

To what extent has this condition been satisfied, given the MLV design and contract?

Answer. In the MLV procurement, an evaluation criterion was that the vehicle have commercial adaptability. DOT participated as an advisor to the Air Force as a member of the MLV Source Selection Advisory Council. We are very satisfied that the Delta II does indeed have commercial adaptability and believe it can be a major competitor in the international market for commercial launch services. In fact, McDonnell Douglas has been actively marketing the vehicle and has secured a number of reservations with deposits, for future launches.

FOREIGN COMPETITION IN ELV SERVICES

Question. China has announced its second signing of a contract to launch a U.S. commercial communications satellite. What are the implications of this event to the U.S. commercial ELV industry?

I understand that the Chinese are offering launch insurance for these satellites. How do its insurance rates compare to those being offered elsewhere, and are the Chinese offering reflight guarantees?

How competitive are the Chinese launch costs, compared to those of other ELV launches? What is the current and expected launch capacity of the Chinese?

Answer. China has announced signed contracts with Teresat and Pan Am Pacific Satellite Corporation to launch U.S. commercial communications satellites. It is our understanding that since these two customers face tight financial constraints, they felt compelled to base their decisions almost exclusively on price.

The price for each launch is reported to be approximately $30 million (excluding insurance), somewhat below prices charged by other ELV launches. We expect that China will have to price its launches below the competition to attract customers because it is a new entrant in the world market and lacks a history of reliability for the Long March 3.

The availability of underwriting capacity from the People's Insurance Company of China reportedly played a rule in Teresat's decision. According to press accounts, the insurance will likely be offered at world market rates.

The Chinese assert that their limited production and launch capabilities permit them to launch a total of 10-12 vehicles per year, only some of which would be available to foreign customers. Two of China's three attempts to launch the Long March 3 have been successful; one failed due to problems with its third stage. China appears unable to increase planned production and launch rates of the Long March 3 during the immediate future.

While we believe that the U.S. commercial ELV industry will generally be price-competitive with foreign launch providers, it also has the following significant non-price advantages over the competition:

Long histories of unsurpassed mission and schedule reliability of vehicle production and launch operations by General Dynamics, McDonnell Douglas, and Martin Marietta;

Competitive incentives for mission success, technological innovation, performance improvements, and cost reduction; and

Economies of scale resulting from Air Force purchases of launch vehicles.

Question. What is the assessment of your Office of the market for the commercial launch of payloads through 1993, and after 1993? Could you distinguish between commercial payloads and Government payloads? What are your fundamental assumptions in predicting this market?

To what extent will the use of fiber optics affect the future market for commercial communications satellites?

Answer. The Department of Transportation estimates that approximately twelve to sixteen payloads per year will require commercial launch services during the next few years. We believe that this level of demand will be sufficient to sustain a U.S. commercial launch industry. In addition, government orders for 23 Titan IVs, 13 Titan IIs, up to 20 Delta II MLVs, as well as potential future orders for ELVs to meet NASA and NOAA mission requirements will increase ELV production bases and thereby enhance U.S. commercial ELV competitiveness in the international market.

Fiber optics will have a competitive advantage in high-density, point-to-point applications. Satellites will have a competitive advantage in low-density, multipoint-to-multipoint applications. Accordingly, we believe that there continues to be a viable market for commercial communications satellites.

Question. What share of this future market should the U.S. ELV industry expect to capture, and on what assumptions do you base this prediction?

Answer. The U.S. ELV industry can expect to capture about half of the market during the next few years. We base this prediction on the following assumptions:

U.S. commercial launch providers will be price-competitive;

Customers will be attracted to the long histories of unsurpassed mission and schedule reliability achieved by U.S. commercial launch vehicles while they were flown for the Government;

Customers will also be attracted to the experience of U.S. commercial launch providers in producing and launching these vehicles;

U.S. commercial launch providers will be responsive to customer needs and desires; and

Economies of scale resulting from production and launch of Delta and Titan vehicles for Government payloads.

Question. Is there an open market in terms of U.S. commercial ELVs launching payloads of other nations or international consortia? If not, what are the barriers that our ELV industry is facing?

Answer. No, there is not an open market in terms of U.S. commercial ELVs launching payloads of other nations or international consortia.

The member states of the European Space Agency (ESA) have given a preference to Arianespace over foreign launch providers. Because European communications satellites are generally owned by governmental entities rather than private firms, there is little opportunity for U.S. commercial launch providers to penetrate the market in ESA nations.

Prior to the Challenger accident, some foreign nations and international consortia, as a matter of policy, divided their launches between Ariane and the shuttle. Since the Challenger accident, NASA no longer provides Shuttle launch services for commercial and foreign payloads, except those that are Shuttle-unique or have national security of foreign policy implications. If international customers continue to divide their purchases of launch services between U.S. an foreign providers, some part of the market will be closed to U.S. commercial launch companies.

Question. I understand that, last June, ESA and Arianespace requested the initiation of negotiations on equitable trade practices, relative to commercial ELV services. What is the status of this request for negotiations—will they, in fact, occur and when? What will be the nature of these negotiations—what can we expect to accomplish, and will these negotiations involve anyone other than the U.S. and ESA?

Answer. ESA and Arianespace have requested the initiation of negotiations on equitable trade practices, relative to commercial ELV services. Through its Trade Policy Staff Committee, the Office of the United States Trade Representative (USTR) is chairing an interagency committee to consider consultations with providers of launch services. The Department of Transportation is represented on the committee. The interagency committee is considering whether negotiation of agreed international rules concerning commercial ELV services would serve U.S. interests. To this end, the committee is reviewing trade-related aspects of government policies affecting launch services, including external support associated with specific cost components and competitive advantages. USTR published a notice in the *Federal Register* (January 22, 1987, pages 2467-8) requesting comments on the desirability and scope of any such consultations. The interagency committee is now reviewing and assessing the comments received in response to the request.

Question. What is your assessment of foreign competition in the world space launch industry, particularly that offered or expected to be offered by Ariane, Japan, and the Soviet Union?

Is Ariane likely to expand its capabilities, and, if so, to what extent?

Answer. Foreign competition in the world space launch industry is likely to be intense.

Arianespace benefits from various forms of assitance from ESA member states, from protected European markets, and from partial governmental ownership. During its critical developmental and testing phases, Arianespace benefited from the high value of the U.S. dollar in foreign exchange markets and from high interest rates. Arianespace is not likely to expand its production and launch capabilities. For the next several years, the Europeans will prefer to focus their space on cutting-edge technological research and development (e.g., space station, Ariane 5, Hermes, Hotol) rather than on operation of existing technology.

Japan has had a small but remarkably successful space R&D program for several years. Japan is developing the H-2 launch vehicle, using domestic technology for launches of communications satellites. Japan expects to launch its first H-2 in 1992 and its first commercial payload on an H-2 in 1994. Japan's launch capacity, however, has been limited by restrictions protecting the fishing industry.

The Soviet Union has successfully launched a large number of Proton vehicles in recent years. More recently, the USSR has been marketing the Proton to foreign governments and firms and to international organizations. Technology transfer restrictions imposed by COCOM (Coordinating Committee on Multilateral Export Controls) nations are likely to remain a serious obstacle to exports of Western satellites for launch from the Soviet Union.

U.S. commercial launch providers now have a timely opportunity to establish themselves in the Western space launch market. They will benefit from long histories of unsurpassed mission and schedule reliability, thirty years of experience in producing and launching vehicles, flexible responsiveness to competitive pressures to improve performance and to reduce costs, and economies of scale resulting from production and launch of vehicles for government payloads.

SATELLITE LAUNCH INSURANCE

Question. Satellite launch insurance capacity has been a continuing problem to most entities offering commercial ELV services. How much satellite launch insurance is currently available, and what are the commercially available rates? To what extent are insurance capacity and rates a barrier to the successful commercialization of ELVs?

Answer. For the last several months we have heard numerous reports that there was a substantial shortfall in launch insurance capacity in the wake of the U.S. and European launch system failures. If true, this would obviously have a detrimental impact on the commercial launch industry, for the financing necessary for commercial launches is directly dependent upon insurance coverage to protect the enormous investments required. Estimates of total worldwide capacity have been in the $70 million range, an amount obviously insufficient to cover advanced telecommunications satellites and certainly inadequate for dual launches.

There is no way of knowing precisely the dimensions of this alleged shortfall, however, as the availability of insurance for any launch cannot be determined until a request for coverage is actually presented to the insurance markets. This situation is now changing, with the approaches to the insurance markets being made by Indonesia for its NASA/Delta launch and by Eutelsat (ECS-4) and Australia (Aussat) for adual Ariane launch.

According to our latest information from insurance industry sources, the results of these solicitations indicate that $110-115 million in launch insurance capacity, and perhaps as high as $120 million per launch, may now be available. Rates for coverage are in the mid-20s (percent)—DOT has been asked not to quote exact figures at this time—and are likely to drop as launch rates increase. Some launches have been self-insured. Thus, we are cautiously optimistic that the situation is improving. At this time, therefore, it does not appear that insurance capacity and rates are barriers to ELV commercialization efforts.

Question. What problems currently exist or are likely to exist in the future in terms of satellite operators obtaining all of the launch insurance they need? If they are unable to fully insure their satellites, what are their options?

Answer. The space launch insurance industry is in an ongoing process of recovering from previous losses. The high premiums being quoted for upcoming launches will increase the insurance pool, thereby helping underwriters recoup for prior losses and ensuring that they can realize profits from insuring high risks. When several successful launches are completed, we will see rates coming down. We are also likely to see more underwriters providing coverage for space activities, thus enlarging capacity. Quite obviously, a significant number of losses will reverse this process and rates will return to current high levels. Should this occur, satellite operators will again face the situation they faced immediately prior to the Challenger accident, when high premiums and inadequate capacity forced at least one operator—RCA—to launch without coverage.

Question. To what extent are ELV manufacturers, both domestic and foreign, offering their own launch insurance or reflight guarantees, and how do these rates compare to those being offered by the commercial insurance industry? What position is the commercial insurance industry taking concerning the establishment of insurance "pools?"

Answer. Arianespace has been offering a "launch risk guarantee" program, charging launch insurance premiums of 11% if the customer agrees to relaunch on Ariane and 13.2% if cash indemnity is sought. The insurance pool at these rates is now fully subscribed. The company appears to be ready to offer a second pool, charging rates a few percentage points higher for each coverage.

The Chinese Government is offering to provide launch insurance coverage through its state insurance company for payloads it launches. Firm rates for this coverage are not yet known, but press reports indicate they will be pegged to world launch insurance rates.

Insurance rates charged by Arianespace are roughly half those currently charged by commercial insurers. Efforts to establish a private commercial insurance pool have been discussed on several occasions but have yet to come to fruition. One reason may be that launch insurance capacity continues to be adequate to meeting existing commercial needs.

U.S. ELV manufacturers have been considering self-insurance or reflight guarantees if insurance capacity proves to be a problem. Specifics of these considerations are not currently available.

Question. To what extent is satellite insurance expected to be written separately for the launch and for the period after the satellite separates from the ELV? What effect would separate policies for the launch and post-separation of the payload have on the avability and rates of satellite launch insurance?

Answer. Although coordination drafts of the Air Force program research and development announcement (PRDA) have been circulated, this requirements statement has not yet been officially publilshed. Negotiations are currently ongoing between DOD and NASA on the specific requirements for heavy lift launch vehicle capabilities to be included in this PRDA. These negotiations are expected to be completed soon and release of the PRDA is planned for the near future.

Insurance coverage for pre- and post-separation phase of a spacecraft launch mission is usually provided by a single policy. In the case of a dual spacecraft launch, each spacecraft would procure its own launch insurance policy. The total cost of the two spacecraft and the launch vehicle, however, are considered to be a single risk up to the time of separation. This results in a situation where, to cite a recent example, launch insurance capacity of approximately $100 million would be available to insure the combined value of the launch and the two spacecraft during pre-separation; post-separation, $100 million in launch insurance would be available for each spacecraft.

This limitation of capacity has led to launch insurance policies with different limits of coverage for the two phases of the launch mission. For example, a policy may be issued with a limit of $50 million during the pre-separation phase and a $100 million limit post-separation. To supplement launch insurance capacity during the pre-separation phase, Arianespace offers its customers a launch risk guarantee as part of its launch service contract. This guarantee of indemnity could be considered a separate policy covering a portion of pre-separation launch risks (loss of the launch vehicle).

Procurement of separate policies for the two phases of the launch mission would be similar to the procurement of a single policy with different limits. Thus, separate policies are unlikely to have an effect on the amount of launch insurance capacity available. Moreover, separate policies could require higher rating due to the splitting of the launch mission risk.

One disincentive to procurement of separate policies could be the possibility of uncertainty concerning the causation and/or timing of a particular launch failure. Such uncertainty could cause problems for the insured in establishing which policy should cover the loss.

DOD HEAVY LIFT VEHICLE

Question. The Air Force recently published a program research and development announcement (PRDA) for a heavy-lift launch vehicle design. This announcement stated that the design should meet a variety of national access to space requirements of DOD, Civil and commercial users.

What is your interpretation of these requirements for the "commercial" users and their relationship with a future Air Force launch vehicle? To what extent could a heavy-lift launch vehicle satisfy future market demands?

Answer. At the present time, there appears to be no commercial launch requirements that could economically utilize the capability of a heavy-lift vehicle, similar to the current situation with the Titan IV. There may, however, be future requirements, perhaps for commercial users of space station, which could efficiently and economically employ a heavy-lift vehicle. If such requirements develop, we would at that time encourage some sort of private sector production and operation of such a vehicle.

We strongly believe that any new launch system developed by the government consider the potential future use of that system for commercial operation. We must make every practical effort possible to avoid repeating the situation we have encountered in trying to commercialize the shuttle, i.e., it being too expensive for commercial operation without some market guarantee which would enable operators to recover costs and some level of profit.

NASA AUTHORIZATION

WEDNESDAY, APRIL 29, 1987

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY AND SPACE,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:05 p.m., in room SR-253, Russell Senate Office Building, Hon. Donald W. Riegle, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR RIEGLE

Senator RIEGLE. The Subcommittee will come to order. We have other members that will be coming and going as we proceed this afternoon. The budget is up on the Senate floor, I think, as is generally known. There are other subcommittees and committees of the Senate meeting at this time, and so we will have, members here as they are able to be here.

Let me welcome the witnesses that are at the table and others in attendance. We are meeting today to discuss the last item in our authorization process prior to the markup of the fiscal year 1988 NASA authorization bill. That item, of course, is the space station, and we have a model of that here on the witness table. That will be described, I am sure, in various details later on in this session.

It is my own view that the space station is one of the most important areas and clearly in the center of America's space program. Having spent a lot of time studying these issues, just speaking for myself I believe that we need to construct the space station. I have supported it in the past, and I support it now.

Having said that, I think it is time also that we get all the cards on the table in terms of where things appear to me to stand at this time.

I think the space station is in serious trouble. I hear that as reflected in the concerns and comments from my colleagues and coming from a variety of other directions as well. It has been more than three years since the President announced his decision to build a space station. Since that time, after two budget cycles, and at least $600 million in expenditures, we still do not have a clear consensus within the administration or the Congress as to the purpose, the cost, the schedule or the design of the program.

We are still waiting for a final decision from the administration to go ahead with the program, and this decision, we are told, will not be made until the next fiscal year. Meanwhile, the Congress and contractors are being asked to commit hundreds of millions of dollars on top of the investment that has already been made on a program that as yet does not really have a clearly defined direction or focus, at least not to the extent that I think is needed.

Our international partners are being asked to agree to a program structure where there are major internal questions about the planned uses of the station by different elements of the United States government. These questions are very important to the nature and extent of international participation, and I think they have to be settled. When I say settled, I mean settled, not to be reopened for press conferences or side door activities or whatever. I think those issues have to be settled now, and they have to be settled once and for all.

The perception is growing that there is something fundamentally wrong in the way that the space station program has been developed, and we on this Committee intend to find out precisely where things did begin to start to move in confusing directions and how we can get this program back on track.

The space station is our Nation's commitment to a civil space program in the future. I believe that we all endorse the concept of joining with our allies in a cooperative venture to develop the peaceful uses of space. I do not think we can afford as a Nation to fail in this commitment. I think the risks of failure are simply too costly and too great for us to even contemplate.

Throughout the recent history of this program we have seen delay, indecision, funding reduction, schedule changes, design modifications and poorly defined goals. I think the space station could be the most important step that we have ever made in space and, in fact, a step that becomes a platform for everything that would follow. Yet time continues to move by, and we are yet to really seize the initiative and take the first concrete steps toward that goal.

As everyone here knows, the Soviet Union has a functioning and manned space station circling the globe this very minute every hour and a half. This week they achieved another first by docking four vehicles simultaneously. They will continue to occupy space on a permanent basis, and that is very clear from all of their actions.

Yet, we can continue with a form of policy paralysis within the administration where we have been unable to reach a clear consensus on a program that has already now been pushed off to at least 1995 at the earliest in terms of when we would actually see this accomplished.

I want to say again I think the space station is this Nation's centerpiece commitment to our future in space. It is a place where we will live and work and not just visit. So I am deeply concerned because I think now we have to require a clear set of goals, that they be articulated for this program and for the space program in general.

Not that NASA can direct this fully, which I think is part of the problem, but with NASA and the other players in the administration I think there is a need not only to nail down the operational judgments that have to be made but I think then the case has to be taken to the American people. I think a base of popular support among the American people has to be developed.

Certainly we in the Congress play a part in that, but as this president probably demonstrates more vividly than maybe any other in modern time what the president thinks, for he is a very powerful force in terms of the country being able to visualize the purpose and meaning of sweeping goals, expensive goals, and how they fit into our future and the gains that are there to be realized if we make a massive and concerted national effort.

So I think very much that we stand at a crossroads at the present time with respect to the future of the space program. I think we can and should seize the moment and take the next logical step, shake out exactly what we are going to do with respect to a space station, get started with it, nail down these agreements with our international partners, and get moving, and get moving not with rhetoric and a lot of bobbing and weaving but with a sustained, systematic, aggressive effort toward this goal.

So if we do not see that, I think this program stands in great peril. I think with the Gramm-Rudman-Hollings discipline squeezing in on the budget as it is and as the law requires and having gone through the budget process as my colleague to my right did in the Senate Budget Committee and others, we are in a situation now where programs that are not clearly defined, not specific and not well articulated are likely to be pushed aside in favor of other activities that are clearly articulated and where there is that kind of focus and that kind of forward thrust.

So the colleagues that I speak to across the Senate are very much of a skeptical frame of mind, and unless we are able to give them a very powerful case, unless that case can be put together in a very compelling way by the administration, NASA and the other groups within the administration in conjunction with ourselves on the Space Subcommittee and full committees, I think we are going to find that the doubts will rise and we will see more drift and indecision. I think it is very important that that be avoided.

Let me first call on Senator Kassebaum, and then I will call on Senator Adams.

Senator KASSEBAUM. Thank you, Mr. Chairman. I really do not have any opening statement other than to commend you, because I do believe this is an important hearing, and it is timely in that we are starting to debate on the budget resolution on the floor. I think that there is some confusion about the costs and the exact progress of the program, and these are things that I am looking forward to hearing and analyzing.

I think it is extremely important to us, and I share that concern and interest with you.

Thank you.

Senator RIEGLE. Thank you, Senator Kassebaum.

Senator Adams.

OPENING STATEMENT BY SENATOR ADAMS

Senator ADAMS. Thank you, Mr. Chairman.

These hearings come at a critical time because there are clear indications that our space program is falling behind its own timetable, and it is lagging behind that of other nations.

In the past few days we have been told that talented young scientists are not joining the program, and we have also been told that we should be radically increasing our spending on space. Now as somebody who supports the space program, I am troubled by the problems we all see, but I do not think they are caused by a lack of funds. Instead, I believe the current crisis in space is caused by a lack of vision.

Neither NASA nor the administration has given us a plan, and the Congress has not been willing to demand one for the past several years. For too long we have tolerated drift and misdirection, and now we are being given remnants of past programs, most of which are burdened with troublesome technological difficulties and rapidly increasing costs.

In the face of the Challenger disaster, we hoped that NASA could heal itself. We thought that we were doing them a service by giving them time to correct their problems. As a result, we accepted a vague answer and even vaguer plans as if they were revealed truths; but we cannot evade reality any longer.

The only truth that has been revealed is that NASA's program is incoherent and incomplete. They have not given the Congress nor the Nation a plan or a vision. Instead, we are fed a series of technological fixes and a process that seems to never reach a conclusion or make a final decision.

I want to be very frank, if I have not already. I believe in the space program and in the space station. I support them both, but in a period of incredible budget constraints there is no way we can give the space program the support that it needs and that we want for a space program that is unable to build public support for and confidence in its operations.

Later this week we may be faced on the floor, and it may happen tomorrow on the Senate floor, with an amendment which would increase spending for some vital domestic programs by reducing spending for the space programs. I tell you that that is the amendment that many of our colleagues find attractive.

People know about domestic programs that work. They also know that NASA has not worked. They cannot give their support to a system which authorizes launches into lightning and into thunderstorms. They cannot give their tax dollars to a space station that might take this form or that form but which apparently will not take form that can be used to launch a manned Mars probe. They cannot give their endorsement to a shuttle program which has not yet corrected its problems and has not been justified as an alternative to expendable launch vehicles.

They cannot get excited about a space program which pledges to make a contribution to speak to peace but then cannot give us a memorandum of understanding with the Department of Defense which defines DoD's role in the space station for our people or for our potential foreign contributors. In short, the American people cannot embrace a program which has not decided what it is or what it will be.

For some time now, NASA and the administration have been unable to tell us where they want to go. Mr. Chairman, in the past we have let them get away with it. Because of this situation, Mr. Chairman, I believe we have to tell NASA, which is what I am trying to express, that what we want and what we are ready to pay for, rather than what they come in and tell us they want some more money for, for programs they can neither fully describe nor accurately cost out.

In that context, Mr. Chairman, my own preference is clear. I go with developing heavy expendable lift vehicles using existing shuttles to assist in building a space station which meets our scientific needs and can further be used as a launch platform for further exploration. That is a vision. It fits. It just happens to be mine. I am certain there are others, but it is coherent.

I do not think this is a time to develop those suggestions. Rather, what I do raise are my concerns about where we are and express my conviction that the space program is worth saving. The only way we can save it, though, is if NASA and the administration worked with the Congress to once again give this program a sense of vision and a clear mission.

I know that is your goal, Mr. Chairman, and I look forward to working with you and the other colleagues on this Committee to shape a clear vision for the space program and develop a cost effective way for translating that vision into a plan for the people who must manage its operation. Without that, Mr. Chairman, this program which can play such a vital role in promoting economic growth and increasing our knowledge in the world will never recover, never again regain public support, and never get the kind of funding it wants and deserves.

How you want to do this, Mr. Chairman, I leave to your discretion, whether you want to call us together as a Committee, whether you want to call together the Committee and certain selected staff people; but if we do not get this vision and we do not get a coherent funding program, I think we stand every likelihood of being destroyed on the floor this week in the budget process and having a program which could have vision and could have specific goals lost.

I think that would be tragic, and I am hopeful that we will be able to do something about it. I stand ready to work with you in whatever kind of program you want to propose to carry that out.

I am sorry my statement was so long. I feel very strongly about it. I feel very disappointed about what is happening, and I am looking for correction anyplace that we can get it.

Senator RIEGLE. Senator Adams, before going on to the next Senator, let me say that I hear what you are saying. It is a very strong statement, and I think it is important that it be said and that the witnesses here today hear it and others hear it.

I will be very much guided by the will of our subcommittee and as a full subcommittee here in terms of how we address these issues. This subcommittee, I think, constitutes a strong base of support that exists within the Senate for the space program, and so if there are these concerns being expressed here.

I think there is a very powerful message in that, and I think coming as it does from you, a former Cabinet officer who has served in a previous administration at the Cabinet level, for you to have reached those judgments I think, having had that other vantage point in your personal experience, I think is a very sober assessment and one that certainly I take account of and I trust our colleagues on the other side of the witness table will as well.

Let me now call on Senator Pressler.

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. Thank you very much, Mr. Chairman.

It would be no understatement to say that this authorization hearing on the NASA space station program is a long-awaited hearing and one that is critical to this Subcommittee's development of the Fiscal Year 1988 NASA Authorization Bill.

After months of debate concerning the scope and direction of the space station program, the administration has finally revealed its revised baseline approach for enabling the establishment of a permanently manned presence in space. I, for one, am interested in learning exactly why the administration chose to revise the previous program into a program that phases in certain capabilities and hardware under the designations of block one and block two.

When one considers that the revised program compared to the previous program will cost more, will achieve its final capability two years later and will defer a significant number of space science opportunities, one is struck by this curiosity.

I would like to emphasize this concern. By all accounts, the Administration's revised space station program is more expensive than the previous program and requires two more years to achieve its final capability, and this I cannot quite understand. There must have been a truly compelling reason to make these changes in the program, and I am anxious to understand the dynamics of this decision.

The revised baseline approach defers to block II a number of noteworthy capabilities and hardware elements and, I might add, subjects them to political risks that they might otherwise not encounter in the previous approach.

Also, as we consider this revised program, it is important to understand how these deferrals affect the utility of the space station, particularly as it relates to space science, during the interim that block II is being approved and developed.

As for the space station international negotiations, it appears that the administration has recently achieved a significant breakthrough in its resolution of the issue concerning the use of the space station for "national security" purposes. Even though there has been no misunderstanding that the Department of Defense might eventually use the space station for R&D purposes, I believe that emphasizing in the international agreements the use of the space station for "peaceful purposes" rather than for "national security" purposes is more in keeping with the true spirit of the program.

Finally, as we consider our space station program, we would be well advised to take note of the recent events of the Soviet space station. Not only did the Soviets successfully dock an international astrophysics laboratory with their facility, but they did so with the same heroics and dramatics that have framed our own space endeavors in the past years. The Soviet space station program should not be the primary motivator for our own program, but, as they continue to live and work in space on a daily basis, it should serve as a reminder that we cannot afford to be too casual in our own program.

These are but a few of the issues that frame the hearing today. The significance of this year's progress in the space station cannot be overemphasized. We are on the edge of embarking on a program that will serve as the centerpiece of our space station for years to come. I hope that this centerpiece is one of which we can truly be proud and is a standard by which all future space endeavors are measured.

With these thoughts in mind, I am pleased to welcome from NASA, the Deputy Administrator, the Associate Administrator of the Space Station Program, and the Chief Scientist of the Space Station Program. We look forward to the testimony of all of these individuals as we seek the answers to these issues before the Subcommittee.

I would say again that my principal purpose for today's hearing is to learn exactly why we are dividing the program into Blocks I and II, and, even with this division, why it is going to cost more, defer certain capabilities and take two years longer to achieve its final capability.

Senator **Riegle**. Thank you, Senator Pressler.

Senator Breaux, do you have an opening comment?

OPENING STATEMENT BY SENATOR BREAUX

Senator **Breaux**. Thank you very much, Mr. Chairman, for having these hearings. Number one, I think they are incredibly important.

Thanks to our witnesses for being here.

I watched television this morning, and they had some of the original astronauts talking about the space program. One of them sort of concluded by saying what America needs is another Sputnik. I would only venture to say we already have another Sputnik, and it floats around and circles this earth every day. It is in the form of the Soviet space station activities.

The challenge is there. I think there is enough blame to go around to everybody, Congress included, administration, NASA, all of us. This president called for a space station commitment in January of 1984. It was revised in 1986. We have had estimates that have gone from one figure to an 80 percent cost increase. We had the White House staff debate it, argue it and change signals. While we are doing that, we are looking at cost figures where other countries are doing things for $200 million where it takes us $600 million.

I just think that it is time that we get some concrete proposals and move on them. The staff memo prepared by the Chairman talks about a tentative recommendation from the administration. Why are we being tentative three years from the time the proposal was first made by the White House? How long are we going to be tentative in what our space station's intent is going to be?

If we are back three years from now with another tentative White House proposal in whatever administration, the Soviet station will continue to circle the earth, gathering valuable information that we are not getting.

So I am not here to assess blame, just to urge everybody to get on with doing the job. Let us quit making tentative recommendations and make final recommendations and let Congress make some final budget decisions and move on with the job. Hopefully we will hear that message from our witnesses today.

Thank you.

Senator **Riegle**. Thank you, Senator Breaux.

Senator Bentsen.

OPENING STATEMENT BY SENATOR BENTSEN

Senator **Bentsen**. Mr. Chairman, thank you for holding this hearing. This is a very important hearing on a terribly important subject. It is important that we build that space station and secure our leadership in space. We can do it with advanced technical concerns and advanced technical knowledge there, but there is another reason, too, I think. I think it is demonstrated by this poster that I saw.

That is a poster of the Russian space station, Mir, that was launched over a year ago. So whatever there is to be learned by being first permanently in space, they are learning it, and they are learning it first.

I agree with the caption: "Shouldn't we be there, too?"

Now, while the administration was refiguring the costs and we were looking at the designs again, the Russians had launched their space station. We, in turn, in the Congress, while we debate what is to be done in regard to that, they are learning what there is to be learned.

Even if we give a go ahead here in the Congress, it is going to take a decade to get it done. I cannot help but remember that story of the famous French Marshall Latway who is out in his garden with his gardener talking about planting a tree. The gardener turned to him and said, Marshall, why do you get concerned? Do you not realize this tree will take 100 years to grow to maturity? The marshall replied by saying, well, then, we do not have any time to lose. Let us get it planted this afternoon.

It will take us a decade here in the Congress, and it will take them a decade to work it out after we decide in the Congress, and I do not think we have any time to lose here. So I congratulate you on calling this very important hearing, and I urge very strongly that we move ahead on it.

Senator **Riegle**. Thank you, Senator Bentsen.

Senator Rockefeller.

Senator **Rockefeller**. No comment.

Senator **Riegle**. Senator Hollings has another commitment and will be here later on. He has left his statement for inclusion in the record.

[The statement follows:]

Opening Statement by the Chairman

Mr. Chairman, approximately one year ago, in this very room, this Subcommittee met to discuss the FY 87 NASA budget request for space station. Our concerns at the time were Soviet competition, the phase C/D (hardware/development) awards, the need to form a consensus on the goals and objectives of the program, and the need to commit to a permanently manned presence.

Despite the assurances that we received last year that progress was being made, we find ourselves at the same critical juncture this year as we meet to discuss the FY 88 NASA budget request for space station. To add to our plight, there does not even appear to be a consensus this year within the Executive Branch as to the cost, configuration and schedule of the preferred space station program. For those critical elements, we are told to wait for the FY 89 budget request. Combine both of these factors with the fact NASA had come down with a severe case of the Tennessee Ernie Ford Syndrome—"another day older and [you're] deeper in debt"—and the challenges that confront this Subcommittee and the civil space program are becoming insurmountable.

Last year, we used the analogy that we were trying to put ten pounds of potatoes into a five pound sack. This year, it looks like we're trying to put ten pounds into a one pound sack. And as hard as we all try, we cannot package the civil space program into that size bag.

According to a CBO study on the FY 88 NASA Budget submitted to the Committee in March, implementation of the pre-accident NASA program in the post-accident environment will require a $14 billion increase over the CBO baseline in the FY 88-92 period. According to an American Institute of Aeronautics and Astronautics' report just released, "if the U.S. elects to be a leading space-faring nation—the civil space budget must be increased as rapidly as practical to a level required to support such a plan—approximately 40% greater than the FY 87 civil space budget or approximately $4 billion a year!"

Simply put, the only way that NASA and the space station program can ever hope for increases of this magnitude is if NASA and the Administration are successful at marketing the civil space program as a national priority. Only then will the program be seen as a budget priority. However, amendments to the pending Senate budget resolution and recent House budget resolution actions warn us that the program has not attained that stature nor has it succeeded in gaining identification as an important element of our competitive posture or technological leadership.

Needless to say, the events of the past year have not done much to reinforce NASA's image or to portray the space station program as well-focused, well-founded or well-directed. Sadly enough, the events of the last year, in particular those related to the space station decisionmaking process, have made supporters of the space station program dubious and opponents of the program confident. Worse yet, the decision to launch the Atlas Centaur makes people question whether or not NASA is cable of prudently using the resources provided for the civilian space program. The civilian space program's credibility has been dealt several serious blows since the Challenger tragedy, and something must be done immediately to correct that image and to put this program back on course.

I'm fearful that we're running out of tomorrows, that we cannot wait another budget cycle to decide what we're going to do. The Nation needs a civil space program, and it needs an effective space policymaking apparatus. The space station might be billed as the next logical step, but the space station decisionmaking process is the most illogical process I've ever seen.

Mr. Chairman, more than a year ago, you and I introduced a bill to reestablish the National Aeronautics and Space Council. That bill was incorporated in the FY 87 NASA Authorization and ultimately caused the veto of that bill—the first ever veto of a NASA authorization. We were told the White House had a proven and effective space policymaking apparatus and that the Congress would not be permitted to legislate the structure of the White House decisionmaking apparatus.

Based on what I have seen over the course of the last year, and especially since last Fall when the NASA bill was vetoed, I think the Administration had better reassess the capabilities of its policymaking apparatus—and I intend to give them that opportunity by adding the Space Council proposal to the FY 88 NASA Authorization.

Mr. Chairman, while NASA, OMB, the Office of Science and Technology Policy, the National Security Council, and DOD are feuding over what the space station should look like, do, and cost, the Soviet space station passes over us every ninety minutes, permanently manned, with a new space science module attached replete with Western European instruments. The race for space is off and running, and we're still walking. The time has come to cut metal and to cut the debate. And it's time NASA and the Administration realize that.

Senator **Riegle**. Before we introduce Mr. Myers, I think it is important to note the very substantial participation by members of the Senate this afternoon. As I say, with the budget debate going on on the Senate floor, I think it highlights the great seriousness with which these issues are viewed. I can tell you that what you are hearing today is being amplified by the comments of colleagues that come to us because of our special responsibilities in this area and say these same things.

I will just make one other point, and that is the space station I think has to be conceptualized as America's first permanent step into space. It really constitutes, if you will, our ability as voyagers in space and as people moving against and toward new frontiers to actually go off the face of the planet to establish a capability in space to learn all that can be learned from that in terms of the scientific and research knowhow, things that would lead to all kinds of applications that could be constructive here on earth, also to position us in terms of an ability over the longer stretch of time to move on out into space and to understand and become a part of this broader universe in which we find ourselves.

So this step is really historic, to think in terms of being able to take ourselves out into that environment and to live and work there on a every day basis.

As Senator Bentsen and others have said, the fact that the Soviets are up there today virtually a decade ahead of us by the time our current plan would have us up to do similar work, taking this out into the mid-90s, the fact that we are ten years behind I think is a very sobering fact, and something that we have to do something to change.

I think we may in the reevaluation process have to think about how we might accelerate our work here and get ourselves out there on a feasible basis earlier in time rather than as Senator Pressler and others have said with a timetable that continues to move further away from us.

The other point I would make is this: it is not enough for the administration to articulate goals, even grand goals like this, and be unwilling to make both the hard policy decisions and the financing decisions that are required. We are not going to be able to achieve these goals unless we are prepared and willing to raise the money that it costs to get this job done. That fact I think has to be faced very squarely in this instance.

If these national goals, whether they are in education or in space exploration or in defense or other areas, are things that are truly in our national interest and we are going to set them forth as goals. We are going to say that we are committed to them, and I think we have to be willing to take the steps that are necessary to amass the resources to see that we actually get it done; that we do not fool ourselves, and we do not fool the American people, but that we back our promises and our dreams with the concrete effort and support and wherewithal that it takes to actually get where we are going.

I suspect in the space program today, in NASA, more and more evidence is accumulating, that everything is being cannibalized. We are being shaved on every edge. I see space science being reduced. I see struggling to try to get the repair done, and I think we are on track on that, in terms of the funding of the replacement shuttle, there is real difficulty in getting the money for this.

I see also a real difficulty in getting a true financial commitment here with space station. Yet I see at the same time—and if I can ask the staff to hold up this chart—and I want to make sure all in attendance today see this.

This chart shows perspectively coming forward in time from where we are now in 1987, this red line being the cost build up of the spending in the Defense Department on space, versus the projected spending in NASA for civilian space activities.

One of the things we are seeing here is there is a crowding out problem going on, where the priority I think within the administration is so clearly on the defense space program side that we are finding it more and more difficult to get even the basic amount of money that we need in NASA to get our things done. I am not surprised to see the slippage in time tables because it seems to me that one tends to cause the other.

Mr. Myers, you have been around a long time, you are an old hand at this and you have come back into the agency and you have come in at a difficult time to try to get the job done. I want you to be absolutely frank with the subcommittee today. I think the only thing that is going to have any usefulness to us in resolving these things is the bluntest statement of the facts that you are able to give us. You bring the finest possible professional reputation, so I would ask you to be very direct and candid with the committee today.

Mr. Stofan and Mr. Moser, I realize these are your first appearances before the subcommittee this year and we want to welcome you and wish you success in your new positions.

Mr. Newman, we are pleased to have you with us again.

Mr. Myers, would you start at this point.

STATEMENT OF DALE E. MYERS, DEPUTY ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY ANDREW J. STOFAN, ASSOCIATE ADMINISTRATOR, SPACE STATION; THOMAS L. MOSER, PROGRAM DIRECTOR, SPACE STATION; AND C. THOMAS NEWMAN, DEPUTY ASSISTANT ADMINISTRATOR.

Mr. MYERS. Thank you Mr. Chairman. I really appreciate the opportunity to appear before this subcommittee this afternoon to discuss the vitally important Space Station program.

I think I would like to just give you a summary of where we are, and I would like to address particularly to Senator Adams that I do not think we are confused.

Senator Adams, I wanted to respond to your comments about our planning and where we stand. I know that NASA has appeared to have some great difficulties. The Challenger accident was a tremendous blow to NASA, and a blow that took some months to recover from. On the other hand, we do have Admiral Truly now in charge of the shuttle program, and our first priority is to come back on line with a shuttle as a safe operating system.

I might add that it is the only device in the world that goes to space and returns to the ground with man. In that respect we are far ahead of the Russians in a program of that nature.

I think we are ahead of the Russians in science. We have done some tremendous things in our science program, and if we had not had the Challenger accident we would have a whole series of really important major planetary programs under way. We really still expect to do that shortly after the shuttle is back in operation again.

These are significant and important long term science programs that I believe are clearly ahead of where the Russians stand. On the other hand, the Russians with the Mir program bring scientists and scientific instruments into their program from the rest of the world.

Senator ADAMS. I just want to know, in response to that, can you launch from the orbit that you are in to Mars with a manned mission?

Mr. MYERS. Yes sir.

Senator ADAMS. I heard differently.

Mr. MYERS. No, the fact is there are many studies about how to operate in space, and we are in the same orbit with the space station that we were with Saturn 5 when we went to the moon, and the same general orbit that we were in when we went Viking to Mars.

There are those who believe that the logical approach to Mars would be to go to the moon, set up a base on the moon, extract material from the surface from the moon and go to a libration point to launch to Mars. There are many different ways of doing it. But certainly from the standpoint of our view, with the importance of the Space Station to many other elements, we believe that the Space Station is a good base, and a good place to store cryogenic fuel and to build——

Senator ADAMS. I am talking about this proposed station.

Mr. MYERS. This proposed station is in the correct orbit to go to Mars.

Senator RIEGLE. I do not want to get too far afield here.

Mr. MYERS. I did not want to stop there. I believe we have in fact looked at those elements of the program.

I wanted to make the point that the Space Station is an absolutely essential next step to all of the planning that we and the rest of the world has ever had in space. The idea is to get low cost transportation to space, and then to build a permanent capability in space for commercial activities, for science, for life science and for finally the exploration beyond the orbits of the earth.

Senator RIEGLE. Let me just stop you there, because I do want to make sure the record is clear on this point, and I have heard things that I do not think square out here. Are you saying that the configuration that you are here to present today is one where a Mars launch could be made from this platform as you now see it?

Mr. MYERS. No, not with the block one configuration, but from the block one orbit. The orbit that this vehicle will be in.

Senator RIEGLE. I understand.

Mr. MYERS. It is an orbit from which you can take off for Mars. It will take additional structure, one of the great things about this design, as compared to other designs in the world is that that structure is a structure which can be expanded laterally to encompass cryogenic tanks that you would then assemble for the fuel to take you to Mars.

Senator RIEGLE. So what you are really saying is, by putting this station which is expandable in the right place that it in fact does lend itself to an adaptation that down the line you could make a Mars launch from an expansion of this particular station?

Mr. MYERS. Exactly. And you have touched the key to me to what the Space Station is all about. It is a station in the right orbit, with the capability of expanding to a whole series of different things that could be done in space.

It is the beginning of a structure which can be expanded with time. And it is a key point here that when we settled on the cost of this Space Station it had been defined in phase B, rather than being $8 billion in 1984 dollars it came out $13 billion on an apples and apples basis.

We recognize that in order to meet early schedules for that program we would have to have an increase in our budget in the next several years. The front end costs were so high that it would be a strong pressure upward in the budget.

The activities that we have been going through with the administration were really to rereview all the elements that we had to see how we could come up with a program which gave us the elements that we were looking for in the initial Space Station: the life sciences, the commercial capability, long duration man in space, and the capabilities to mount scientific instruments, both internally and externally on the Space Station, and, with that, put ourselves in the position that we could grow in the direction that would give us the further capability in the future which could be this configuration that you see here, which is the one that came out of our phase B definition. Or it could be in the direction of lateral building of structure out to the side to contain the cryogenics that would be required for either a lunar base or a mission to Mars.

I think the important thing to get across is that even though we, NASA goofed in the original estimate of the Space Station, that $8 billion, or goofed on the other end by defining advanced technology systems as a thing that increased its cost so that its cost came out $13 billion.

We will take the blame for that, because it did distort our budget requirements and put us in the position where it did not seem like the right thing to do. And with our discussion within the administration we have come up with this idea of a block one, block two, which allows us to get an absolutely first class station with some features that no one else in the world has in space, and puts us on a road to go in the direction that we will want to go in the future.

We believe today that block two is the direction that we would want to go. My personal view is that the reaching for Mars will come later, perhaps after 2000 and we will then add the structure to do something of that nature.

But whenever we decide to do something like a permanent lunar base or a Mars mission, we would be in the position to add the structure and the capability to this Space Station in this orbit to do that job. I think that is an important element and an important perception that I do not think has really been understood.

I do want to have the Committee understand that we believe this is a very good space station at block one. We believe it will be a better space station someday at block two. We believe it has the capability to grow in the direction that it ought to grow as our program develops.

You are going to be hearing later from Dr. Stofan about the way we have built into the system the capability to grow. And I think that is another important part of the design criteria that we brought into the program.

Having said all those, I want to say that we also in our planning, are working on the thing Senator Adams that you are very properly concerned about, the vision of NASA. I call it strategic planning because of my background in industry. Where do we want to eventually be. Where does NASA and the Congress and the United States, where do we all see that we want to be in the future. I will say that Dr. Fletcher has taken that on with an absolute vengeance. He is working extremely hard on that whole picture of where should we be in the future.

He has Dr. Sally Ride working on it, the astronaut that has flown the shuttle but has been on the Payne commission, the President's commission on the future of space. She is doing a beautiful job of tying together all the elements of the civic leaders, the industry, the technologists, the scientists, trying to bring together for Dr. Fletcher the elements that would lead to that vision of where NASA should be in the future. And I can only say that every one of the elements that we are working on requires a space station. They are clear, it is absolutely sure that we are going in the direction that will require a space station of this nature.

I think that, therefore, although we do not make it clear to the public, we probably do not make it clear to you gentlemen here, I think we have a plan that is coming together and will be together by this summer that brings together the shuttle, the Space Station, the science, the expendable launch vehicles and the whole picture of where NASA is going in space.

I have not mentioned, by the way, our aeronautics program or our space technology program, but we have been outstanding in our aeronautical program and working with industry.

We have not been as outstanding in our space technology. We think it is extremely important that we really begin to move hard in space technologies to give ourselves a base for where we want to go in the future. I believe that we have that beginning to happen now and in our 1988 budget request.

The aerospace plane technology is another one that we are working together with, we are doing the technology in hypersonic aerodynamics and fuel cooling and the integration of the inlets with high speed flight. All is a part of another really strong outreach by NASA in high technology, and one in which we are doing the technology and the Air Force is doing the project management of a program somewhat like the X-15 that will bring a really aggressive aeronautical program together.

So I do not think that we look like we got our act together yet, but we are working on it, Senator, and I think we are going to have it one of these days.

Now I would like to cover some specific things on the Space Station before I ask Dr. Stofan to cover in more detail. We have completed extensive reviews of the Space Station configuration and have conducted internal cost reviews, both by the program and inside NASA with an independent cost estimate. We have met with the administration on the results and the administration has reaffirmed its commitment to a permanently manned Space Station.

NASA recently released requests for proposals to the industry for this phased development of the Space Station, including estimates for an enhanced capability configuration. Dr. Stofan is going to cover what the configurations are, but that one that is the model there is what we now call the enhanced configuration. These RFPs ask industry among other things to identify ways to reduce the cost of their respective work packages.

In addition, an independent technical and cost review will be conducted in parallel with the development of the industry proposals to further assure that the Space Station program is well conceived and that the cost projections are sound.

The results of these activities will be a sound Space Station configuration, a solid understanding of design issues, and a level of funding that will enable NASA to undertake a successful development program.

That the administration has reaffirmed its commitment to a permanently manned station at a time of severe fiscal constraints reflects the recognition that the Space Station is an important element in realizing U.S. leadership in space. I know this subcommittee shares the President's commitment to space leadership. In considering the NASA Fiscal Year 1988 budget request, I urge you to share this commitment to the Space Station program as the centerpiece of that leadership.

I believe the phased approach we are proposing appropriately balances the need for budgetary restraint with the need to move forward with the Space Station. To meet our responsibility to the future we have devised a program that meets key Space Station objectives. The revised baseline configuration as currently envisioned, first, establishes a permanent manned presence in space, second, develops a diverse set of capabilities for what is really a research center in space. The Space Station revised baseline configuration includes pressurized volume, attached payload accommodations and a polar platform.

Third, it maintains significant international participation, including elements of a Canadian mobile servicing system and pressurized modules for both Europe and Japan.

Fourth, it provides for enhanced capability through Space Station evolution, when and if such capabilities and required and approved. I should point out, Mr. Chairman, that the phased program does not reduce the requested NASA civil service necessary to do the Space Station job at the various NASA centers engaged in the Space Station program. Direct contractor support levels may be reduced slightly.

Recently a significant step has occurred with respect to the international respects of the Space Station program. I am pleased to be able to tell you that negotiations with our partners, Europe, Japan and Canada, are once again underway. Tomorrow, NASA and the Department of State negotiators will meet in Ottawa with the Canadians to discuss the Space Station agreements. I believe we clearly maintain the administration's objectives which protect the full range of U.S. interests.

Clearly one of these U.S. interests is the development of an international Space Station complex for civil purposes as envisioned by the President in his personal invitation to our partners three years ago.

While Mr. Stofan and Mr. Moser will comment later in greater detail, let me briefly outline the Space Station revised configuration and cost estimate to which NASA is now committed.

As currently envisioned, the revised baseline configuration features a 110 meter long horizontal boom to which are attached in the middle three pressurized laboratories and a pressurized habitat. At each end are located photovoltaic arrays generating a total of 75 kilowatts of power. Two attached points for external payloads are provided along this boom, which will be made of an advanced composite material. The revised baseline configuration includes a Flight Telerobotics Servicer. And as noted earlier, it includes a Space Station platform that will fly in polar orbit.

We estimate the cost of the revised baseline configuration is $13 billion in 1988 dollars, which is $10.9 billion in 1984 dollars. The reason we always include the 1984 dollars is that $10.9 is the number that compares with the $8 billion estimate that we had in 1984 dollars. But the cost in today's dollars is $13 billion.

In addition we estimate that the basic engineering and technical support activities at the NASA field centers will need to be augmented by approximately $1.6 billion in 1988 dollars. That is over the next eight years to support the Space Station.

Our cost estimates include the request for Fiscal Year 1988 of $767 million so very critical to moving the program forward. Any significant reduction jeopardizes our goal of realizing a permanently manned capability in 1996. We must have sufficient resources to support the substantial engineering talent that must be brought to bear in the front end of the program.

In support of the Space Station program the National Research Council will conduct this spring and summer an independent program cost review. In response to requests from the administration, the independent review will be responsive to varied concerns of the user communities, the administration and the Congress. It will conduct a thorough review of the program, examining requirements, cost, capabilities and schedule.

The review will also examine the full range of alternatives to realizing the highest national priorities of the Space Station program. This NRC review will be completed by September 1, 1987, and will report to the Office of Management and Budget, the Office of Science and Space Technology Policy, and National Security Council and to NASA.

Working with NASA, the NRC will examine a full range of cost options. Decisions on the total Space Station costs, capability and annual funding projections will be incorporated in the Fiscal Year 1989 budget request.

In addition, the administration plans to recommend specific legislation for a rolling three year Congressional commitment and a total-cost ceiling on the program.

I believe such a three year commitment would be a strong tool for the control of Space Station costs.

Mr. Chairman, this concludes my prepared statement, and I would like to now, if it would please the Chairman, to have Mr. Stofan give a five minute briefing on the definition of our new baseline configuration.

Senator RIEGLE. Please go ahead Mr. Stofan.

Mr. STOFAN. Thank you, Mr. Chairman. I would like to submit the statement that I prepared for the record, but I think a brief summary would shed more light on it.

Senator RIEGLE. The whole statement will be in the record, and let us have your summary.

Mr. STOFAN. Let us have the lights dimmed and we will get to the slides please.

[Slide]

Mr. STOFAN. I think one thing that Mr. Myers said that I would like to reemphasize is again, is that I would like to really stop calling this a Space Station. I think maybe the Russians have a Space Station.

This is a research center that we are putting in space and I think it could be looked at from the point of view that NASA has decided to build another research center. It is not going to be built here on the ground, it is going to be built in space and I think that is the proper perspective looking to the future for what we are proposing.

Again, the elements of this research laboratory are pressurized laboratory, attached payloads, unmanned platforms.

The attributes of that are permanent presence, interactive crew, repetitive access to the station and a high level of power on the station to take care of foreseeable growth.

The disciplines that are enhanced, life sciences, material processing, astrophysics and earth sciences. May I have the next one please.

Again, to go into this a little bit deeper, the question of what are we going to use this initial station for, and again I am referring to the block one configuration for the Space Station, in life sciences it enables studies of fundamental behavior, living cells, it enables new characterization of the human as a system.

We must, if we want to go on to the Moon or Mars, space qualify humans to do that. We do not know how to keep men in space for that period of time today.

The materials research, again in size and pressurized volume, this is key to the future material research for this country. We can fabricate defect free crystals, gallium arsenide for chips, produce large pure biological crystals essential to identification of basic molecular structure which will ease the disease identification and hopefully treatment.

In astrophysics, even with the horizontal boom, only the horizontal boom we do have to attach points for payloads, we can use observations up, attach points looking out for astrophysics or planetary. We can look down for the earth sciences to aid in the earth sciences program.

Also our polar orbiting platform will have a whole host of earth viewing instruments on board.

Now, the revised baseline configuration. Just briefly, we came out of extensive review in the fall, a Critical Evaluation Task Force, August to December of 1986.

We developed a revised cost estimate that came out quite a bit higher than the one that was made several years earlier on a different configuration and not the station that had the capabilities of what we are proposing today.

In February and March we had extensive discussions on the cost, capabilities and schedules with the OSTP, NSC, OMB and ourselves, and we came to an agreement on what to proceed with.

In April, the administration agreed to a phased approach, a $14.6 billion in 1988 dollars revised baseline configuration, and that includes the basic technical capabilities at the centers.

We released the RPFs over this past weekend. We also agreed to the independent counsel of the NRC to take a look at the phased approach and the full up configuration, and incorporation of the program scope into the 1989 budget request.

Again, the revised baseline configuration, U.S. lab, and hab modules, accommodation of attached payloads. We do have the polar platforms, the ESA and NASA polar platforms. We have 75 kilowatts of photovoltaic power.

We have the entire international participation with just a small part of the Canadian mobile servicing center being moved to the block two. A crew of four, six and then we can expand to eight, and again, as Dr. Myers pointed out, extremely important, the station is designed to evolve and grow, not only to the enhanced capability, but on to when we see what the future needs and where the goals and objectives of NASA become.

Second one is the, we add the solar dynamic power system, and again, say 50 kilowatts. We will study that over the next year or so to see what, how much power we do have to add in the future. We will be able to accommodate attached payloads on the upper and lower boom and three more attach points will be added.

We will add a servicing bay, and again we will define and provide a co-orbiting platform that can be serviced by the station.

This shows the revised baseline configuration on the left, with the horizontal boom showing the photovoltaic arrays and the four modules, the hab and lab, the ESA and the Japanese module.

It also shows the radiators and the attached payload points and the manipulating arms that are located on the modules and a remote or movable manipulating arm that we are working on now defining with the Canadians to aid in the assembly and operation of the station.

On the right is what we call the enhanced configuration, or when we add the block one to the baseline configuration, we add the upper-lower booms, the servicing center, the attached points and the solar dynamic power.

Again, I think pictures of this have been passed out. It shows the details of what I had explained to you before, and shows it with relation to the shuttle. This one I think shows a little more clearly the remote manipulator arms that are so important to cut down the EVA for assembly, maintenance and repair.

Revised baseline configuration assembly sequence, we have just recently reconvened and gone through the assembly sequence with part of the group of people that did the CETF activity last fall went back and looked at the packaging again, and we in fact still are looking at it again. But the first looks by the sixth flight, we would have man-tended, by the eleventh we would have a permanent man configuration, and the complete revised baseline by the sixteenth flight. This also includes two flights for the ESA polar platform and the NASA polar platform.

ESA will launch theirs on an Ariane, and we are looking at launching ours, a possibility on the Titan IV out of the west coast. If that was the case, there would be 14 shuttle flights then to get us to the revised baseline configuration complete.

Again, on the right, shows the definition phase that brought us down through the revised baseline configuration of April 1987. On the right hand side is the development, contract start date. These are goals that we are shooting for in November of 1987. Preliminary design in January of 1989, critical design review in 1990, first element launch March 31, 1994. One year later, man tended capability, permanent man presence in early 1996.

Again, I think the revised baseline configuration realizes a permanently manned presence for a Space Station or a Research Center, provides diverse capability, pressurized volume, which is extremely important for life sciences and materials processing. We can accommodate some of the attached payloads. We do have a full up polar platform.

We maintain our total international partnership in this endeavor. Again, very, very important, it was pointed out earlier, it supports the future evolutionary growth as the goals and objectives of NASA become clear.

Again, it incorporates a budget commitment of $14.6 in 1988 dollars that are consistent with the budget and made us go back and look and come up with this configuration.

Thank you, Mr. Chairman.

[The statement follows:]

STATEMENT OF ANDREW J. STOFAN, ASSOCIATE ADMINISTRATOR FOR SPACE STATION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and distinguished members of the subcommittee, the Space Station program has made significant progress in the last year. This afternoon I would like to review this progress with you, explain the FY 1988 Space Station budget request and continue discussions with this Subcommittee that are so essential to a successful Space Station program.

Before doing so, let me first comment briefly upon the Space Station, its significance to science, and its importance to our Nation's future in space.

The Space Station will be a unique and versatile complex—unique because it will provide us with a permanently manned presence in space; and versatile because it will provide truly diverse capabilities. This diversity is reflected in the Station's pressurized laboratories, accommodations for attached payloads, and free-flying unmanned platforms. NASA, in cooperation with its international partners, is developing a research laboratory that will add significantly to our storehouse of scientific knowledge. This laboratory will also stimulate new technologies and help realize the potential of commercial operations in space. Combining both manned and unmanned systems, the Space Station will offer an unmatched capability that can evolve in time as new demands and new circumstances arise.

As a laboratory in space, the Station will support research of fundamental importance. The Space Station's microgravity environment, high levels of power, and permanence in orbit, will enable scientists to make new discoveries in materials research and life sciences. Space Station scientists, working within pressurized modules, will be able to conduct research leading to large, defect-free crystals essential to the development of the next generation of computers. They will be able to produce pure biological crystals important for the identification of basic molecular structure, and thus helpful to the development of new medicines. Other scientists will be able to study the fundamental behavior of living cells and help characterize and understand the human body as a self-contained, complex, ecological system. They also will be able to penetrate further the mysteries of human physiology as it is affected by extended space flight.

Yet the Space Station's substantive research capabilities include far more than its pressurized volume. The horizontal truss structure of the Space Station offers a valuable location for the placement of external payloads. Sophisticated telescopes and specialized instruments will be able to look out to the stars while other instruments will be able to look down upon the Earth. Utilizing the Station's orbit, scientists will be able to monitor and examine phenomena such as the tropical rainfall. This rainfall is a dominant factor in understanding the Earth's hydrological cycle which is a critical element in understanding the periodic variability in the Earth's weather pattern.

Complementing the Space Station manned base will be the free-flying, unmanned Space Station platforms. From the beginning NASA's architecture for the Space Station has incorporated unmanned craft within the program as well as the larger manned system. The platforms are essential elements of the Space Station Program. One will be developed by the United States and one, assuming negotiations are successful, will be developed by our Space Station partners in Europe. Both will be in polar orbit, providing valuable data about our planet. Later, as the manned base capabilities are enhanced, a co-orbiting platform will likely be developed. This platform will support scientific instruments in the fields of astronomy and astrophysics.

However, the Space Station's value extends beyond the experimental and observational sciences. Scientific instruments, be they in a laboratory or on a boom, require maintenance, upgrading, repair and replacement. The Space Station we are designing will accommodate these functions. The Station will not only be a research laboratory of unparalleled capability, it, because of the manned presence, can be a servicing center of considerable practicality. Our experience in space to date confirms the importance of accommodating these functions. Things do break and they don't always work exactly right. They need "time in the shop." The Space Station can be that shop. It could service many of the scientific instruments it carries as well as provide,—in the future—for extended service of those free flying spacecraft that are within range of the Station manned base.

Perhaps the most significant feature of the Space Station, essential to its utility for both science and technology, is the permanent nature of its crew. Men and women will be aboard the Station base full time, 24 hours a day, 365 days a year. This makes the Space Station different from what we have done in the past. It makes it a system of enormous capabilities. Humans are the most sophisticated machines of all. Their creativity, their dexterity, their ability to perceive, to interact with instruments and to respond to the unexpected are unique and essential. The Space Station will be designed to exploit these human capabilities. And by providing a permanent presence, the Station will enable these capabilities to realize their fullest potential.

Mr. Chairman, let me now speak to the Space Station from a somewhat different perspective.

The Space Station represents a commitment to leadership in the future. Today, United States leadership in space is being challenged. Spacecraft and launch vehicles of considerable sophistication and proven reliability have been developed and flown in Europe, Japan, China, and the Soviet Union. These countries understand the utility and value of space systems. They understand that profit, productivity, prestige and national strength are the products of a space program. They are committed to an extensive and visible presence in space. Our response must be to press forward with projects that are intellectually stimulating, technically demanding, and genuinely useful. Often, we will do this together with our friends and allies, in cooperative endeavors. Sometimes we will do it by ourselves. No nation can match our experience in space or our technical capabilities. If we apply these with vision and imagination, if we chart the future with programs such as the Space Station—with its range of capabilities unlike any other space system—then leadership in space will again belong to the United States.

OVERVIEW

The past year has seen a number of significant steps in the Space Station program. Before reviewing with you our accomplishments of last year and our plans for the year ahead, let me discuss these improvements with you for they represent significant progress. Significant steps in configuration and program planning, program managemen and organization, operations planning, and procurement planning have been taken.

Configuration and program planning

Since January, 1984, when President Reagan directed NASA to develop a permanently manned Space Station, NASA and its partners in industry have made substantial progress in establishing a Space Station configuration and in conducting the preliminary engineering that will enable Space Station concepts and technical analyses to be the basis for a successful development program.

Space Station preliminary engineering has been conducted along three principal avenues. The Phase B definition and preliminary design activity, a 21 month period of intense analysis by NASA and industry, has provided strong understanding of Space Station systems design. This design analysis has been enhanced by a special technical review of the Station's configuration conducted last summer at the Langley Research Center. The three year NASA-industry advanced technology program comprises another avenue. It has matured technologies that will substantially improve Station subsystems and capabilities. The third avenue has focused upon the utility of the Space Station. An extensive interaction with the user communities, in particular, the involvement of the Space and Earth Sciences Advisory Committee's Task Force on the Scientific Utilization of the Space Station, has led to an understanding and accommodation of user requirements. The preliminary engineering done so far has been extensive. The three avenues have converged to give NASA confidence that the Space Station program is ready to proceed with hardware development.

Complementing this technical analysis has been a review of Space Station Program costs. NASA, at the direction of the Administrator, conducted a major internal cost review of the program from September, 1986, through January, 1987. A special team of NASA program and resources experts were assembled to carry out a thorough, top-to-bottom examination of Space Station Program costs. Our contractors and the NASA field centers participated in the analysis. The NASA Comptroller's Office reviewed the results. What emerged was a thorough understanding of cost parameters and a revised cost estimate for the Program. Development of such an estimate was consistent with NASA's original intent of revising Space Station cost projections at the conclusion of the Phase B definition and preliminary design analysis.

The NASA Administrator presented this revised cost estimate to senior officials in the White House during February, 1987. Discussions occurred throughout February and March during which NASA further analyzed options and explored means for reducing costs. After much deliberation, agreement was reached on a phased approach to the program and on a revised baseline configuration that effectively balances the need for fiscal restraint while establishing a permanently manned Space Station in the mid-1990's.

The revised baseline configuration achieves a permanently manned capability in the mid-1990's. Derived from the dual keel configuration developed last fall and the results of the technical review at Langley, it features a 110 meter long horizontal boom to which are attached in the middle four pressurized modules. The modules will sustain a crew of six to eight. Linking the pressurized modules are resource nodes. Containing systems formerly located on the outside, the resource nodes will improve crew safety and productivity. At each end of the boom are located photovoltaic arrays generating a total of 75 Kw of power. Two attachment points for external payloads are provided along this boom. The revised baseline configuration retains the Flight Telerobotic Servicer. It also includes an unmanned, free-flying platform in polar orbit. The configuration establishes a permanently manned presence and provides for meeting new requirements and accommodating new technologies in an evolutionary fashion.

The revised baseline configuration allows for meaningful international participation. The four pressurized modules of the Space Station manned base include laboratory and habitation modules to be provided by the United States and, again assuming negotiations are successful, laboratories from both Japan and the European Space Agency (ESA). Europe is also expected to provide a polar orbiting unmanned platform and a Man-Tended Free Flyer. Canada is expected to provide the first phase of a Mobile Servicing System (MSS). Such international participation is extremely valuable. It supports the U.S. foreign policy objective of strengthening ties with our allies. More pragmatically, it means we will have a more capable Space Station.

The revised baseline configuration offers a diverse and substantial set of capabilities. Considerable pressurized volume is provided via the modules and nodes. Attached payloads are accommodated. 75 Kw of power, far more power than has ever been provided on a spacecraft, will be available to Station users and operators. And the polar platforms provide capabilities that complement those of the manned base.

Extensive technical and cost analysis by both NASA and U.S. industry exists regarding Space Station enhancements beyond the revised baseline configuration. NASA has outlined an enhanced configuration that illustrates one way the capability of the Space Station could be expanded in the future. This enhancement builds on the horizontal boom and module pattern of the revised baseline. It would feature dual keels, two vertical spines 105 meters long joined by upper and lower booms. The structure carrying the modules would become a transverse boom of a basically rectangular structure. The two new booms, 45 meters in length, would provide extensive accommodations for attached payloads, and would offer a wide field of view. Power would be increased significantly, with the addition of a solar dynamic power system. Satellite servicing capabilities would be provided, in large part by the addition of a U.S. supplies servicing bay. This potential enhanced configuration might well include an unmanned, free-flying platform that would co-orbit with the Space Station manned base.

An independent program and cost review of the Space Station Program will be undertaken this spring and summer by the National Research Council (NRC), in response to a request from the Administration. The independent review will be responsive to the varied concerns of the user communities, our potential international partners, the Administration and Congress. It will conduct a thorough review of the program, examining user requirements, costs, capabilities and schedule. The review will seek to identify a full range of costs and configurations to realize the highest priorities of the Space Station Program. This NRC analysis will be completed by September 1, 1987 and will be reviewed by the Office of Management and Budget and by NASA as well as by the Office of Science and Technology Policy and the National Security Council. Working with NASA, the review will examine a full range of cost options. Decision on the total Space Station cost, capability and annual funding projections will be incorporated in the FY 1989 budget request. In addition, the Administration plans to recommend specific legislation for a rolling three-year Congressional commitment and a total cost ceiling on the program.

Program management and organization

As the Space Station program matured, it became evident that the management approach used during the definition phase would need to be restructured for the development phase. This was not unexpected; initial organizational structures of large complex aerospace projects traditionally evolve over time, just as the technical parameters of such projects change. Given the breadth and depth of the Space Station program, it became imperative that a strong and stable organization be in place to manage the program during the detailed design and development phase.

Late last summer a new Space Station organization was established. It features a centralized management structure, highlighted by a new technical program office to be located in Reston, Virginia. This program office reports to the Office of Space Station at NASA Headquarters. Dr. Fletcher approved the new organization for the Space Station Program on December 23, 1986. Principal functions of the Office of Space Station, which I head, are policy direction, budget formulation, and external affairs. These are essentially "up and out" functions. In contrast, the Space Station Program Office in Reston will be responsible for the overall technical direction and content of the Space Station program, including systems engineering and analysis, program planning and control, resource and configuration management and the integration of all elements into an operating system. I describe this as the "down and in" function. Both areas of responsibility are closely coordinated in order to assure effective management.

The Space Station work packages are heavily interdependent and the resultant interfaces have a high degree of functional complexity. This demands a strong systems engineering and integration capability. The Space Station Program Office organization, supplemented by a support contractor, will provide this capability. Considering the strong imperative to achieve economy as well as authoritative central control, it is important to use the NASA field centers' institutional capabilities that exist rather than to attempt to duplicate them. The systems engineering activity will be conducted in part through the NASA field offices.

Operations Planning

To guide the next and more detailed planning for Space Station operations, we have completed an Operations Management Concept which is intended to promote maximum user autonomy and cost effectiveness through simplification of the management structure. The review of this concept was comprehensive, involving our international partners and the user community. While gratified by the acceptance of this first step towards an operational plan, we became aware of the need to retain the broadest possible base of participation and input as our work progressed. As a result, in September 1986, I established an Operations Task Force to provide advice on how best to implement the Operations Management Concept. This group, which includes members from all organizations within NASA and the user community, both domestic and international, and which has involved industry, academia, and other parts of the private and public sector, has now completed the bulk of their work and are presenting their findings and conclusions to me and other NASA officials. Once this review is completed the concept will be baselined and used for developing our operations capabilities and for understanding and managing operations costs. Earlier, the Task Force provided commentary to those preparing the RFPs.

Procurement Planning

NASA has now released the four major Request for Proposals (RFP) for the detailed design and development phase of the Space Station. It is time to initiate this phase of the program and to competitively select those industry teams with whom we will negotiate contracts for Space Station hardware.

The contractors will be requested to submit two proposals. One will incorporate a phased approach to Space Station development, to include the revised baseline configuration as well as a later enhanced capabilities design. The other proposal will be for simply the enhanced capabilities Station. In addition, NASA will ask the contractors to submit ideas for lowering the cost of their respective work packages.

The RFPs themselves have been well coordinated. The four work package Centers' work statements have been reviewed to clarify inconsistencies, and eliminate overlaps, or omissions. Common language has been incorporated into the RFPs for general requirements applicable to all. In addition to the individual source evaluation boards (SEBs) at the NASA centers, a Space Station Program Procurement Coordination Committee, which includes senior program management, has been established to coordinate the work of the center SEBs and to make decisions as necessary.

In addition to the planned design and development RFPs, the Space Station program developed an RFP for a program support contractor (PSC). This RFP was released to U.S. industry on February 3, 1987. The selected contractor will support all aspects of the program office activities, but the largest part of the effort will be systems engineering and integration. This contractor will support the NASA Space Station Program Office in Reston as well as the field offices to be established at five NASA centers. The main focus of the PSC will be to assure the Space Station is designed, verified and can be operated as one integrated system. We expect contractor selection this summer. This will enable Program Office and the field offices to be fully operational shortly thereafter, in readiness for the start of the hardware contracts.

The data management and information systems activities include the establishment of the Technical and Management information System (TMIS) and the Software Support Environment (SSE). During the past year, in addition to maintaining a limited information management capability in support of definition activities, we completed a functional definition of TMIS and released an RFP for a systems integration contractor to design, acquire, and implement TMIS. The Boeing Computer Services Company has been competitively selected for the TMIS activity, which will be implemented in increments. The first increment is scheduled to be operational by December 1987. Additional increments of capabilities will correspond to the requirements of the program as the development of the Station proceeds.

The Software Support Environment (SSE) is defined as the integrated set of tools, policies, procedures, training, and system software that will be used to develop, integrate, and maintain all of the program's operational software. The SSE is an important key to the successful development of the initial Space Station program and its longer term cost-effective evolution. The benefits from the SSE can only be realized if that environment is in place and available before its capabilities are needed by the program's software development community. During FY 1987, we move aggressively ahead with the procurement of an SSE system contractor. It is important to emphasize that the SSE is truly a program-wide initiative. The RFP was issued for industry response in September 1986. At the present time, the proposals submitted by industry are under evaluation by a program-wide SEB. We are on schedule in the procurement process and plan to recommend an industry source to the NASA Administrator in late Spring with a contract start in the May-June 1987 timeframe.

The Flight Telerobotic Servicer (FTS) is a highly automated telerobotic device capable of precise manipulations in space. Congress has directed us to develop such a device, and it is part of the revised baseline configuration. Available for Space Station assembly and operations, the FTS and its technologies are expected to have applications in both space and on the ground. The principal activity planned for this year is the initiation of the FTS system definition phase. We hope to release an RFP shortly, and upon evaluation and selection, initiate two or more parallel Phase B studies.

HIGHLIGHTS OF FISCAL YEAR 1987

The depth of the Space Station program is perhaps best illustrated by some of our accomplishments. I would like to review a few of the highlights of the past year.

System definition/program management and integration

In December 1986, we reached a major program milestone: the conclusion of the twenty-one month contractor effort of the system definition and preliminary design phase of the Space Station program. This effort began in April 1985 and involved five NASA Centers: the Marshall Space Flight Center (MSFC), the Johnson Space Center (JSC), the Goddard Space Flight Center (GSFC), the Lewis Research Center (LeRC), and the Kennedy Space Center (KSC), as well as eight contractor teams. Other support activities have been conducted by the Ames Research Center (ARC), the Jet Propulsion Laboratory (JPL), and the Langley Research Center (LaRC).

During this period, each center with its respective contractor teams conducted in-depth trade studies, analyses and assessments of its assigned portion of the Space Station. This process involved comparisons of subsystem designs, components and technologies with respect to the major, overall requirements such as user accommodations, safety, reliability, ease of maintenance, high productivity and lowest life-cycle costs.

The results were submitted to the Space Station Control Board (SSCB) which has representation from the user community; the operations planning community; safety, reliability and quality assurance office; international partners and other communities important to the overall Space Station design. This review process determined the configuration from which the revised baseline configuration was derived.

Two examples of major decisions during the twenty-one months of definition and preliminary design are:

1. The change from a hydrazine to a hydrogen/oxygen propulsion system for reboost and reaction control. Since these fuels can be generated on orbit by water electrolysis, only water needs to be resupplied. Water is likely to be available in abundance due to the materials processing activity requirements. Minimizing the amount of hydrazine, a highly corrosive and toxic fluid, is another benefit of this decision.

2. The closure of the environmental control and life support system (ECLSS). This application of advanced technology is one that will make the Space Station a more viable entity from a logistics resupply cost point of view. Both air and water will be regenerated from metabolic waste and hygienic water, necessitating the resupply of only food and nitrogen. The decision to use an earth-like atmosphere was made to allow life science experimenters to use valid control experiments on the ground.

Advanced technology development

During FY 1987, the funding for the advanced technology development effort for the baseline Space Station will come to an end. This program has been conducted in conjunction with the Office of Aeronautics and Space Technology since 1984. This work has been successful in increasing the acceptance of new technology into the Space Station preliminary design. As a result, the expected performance of the Space Station has been enhanced. A few examples of new technologies that are included in the preliminary design as a result of the Advanced Technology Development Program are: power management and distribution at 20 kHz; two phase heat transport and dissipation; closed loop life support; and a high pressure, high mobility EVA suit.

The final measure of the success of the advanced technology program will be the performance of the Space Station on orbit. I expect that increased confidence will be achieved throughout the development program with the prototyping and selective STS flight experimentation of some of these technologies. It will be at those points in the program that reduction in development risk achieved by these advanced technology development activities will become more apparent.

BUDGET SUMMARY

Mr. Chairman, I would now like to describe the program areas we plan to fund in FY 1988. The budget request I am presenting today will support substantial and steady progress in the Space Station program. With this level of support, we can maintain the program's considerable momentum and meet the President's goal of establishing a permanently manned presence in space by the mid-1990's.

Our total FY 1988 budget request for Space Station is $767 million. Attached to this statement is a chart which summarizes our FY 1988 requirements and our use of funds previously made available.

The budget request provides funding for operations definition ($7 million) to plan for an efficient flow of ground and flight systems during the operational phase, and transition definition ($5 million) that will cover studies leading to a logical and orderly evolution of Space Station systems into the next century. In addition, our request contains $22 million for the FTS.

The request for actual development funding is $733 million. This will provide for the development of pressurized laboratory, habitation and logistics modules at $196.5 million; and assembly hardware and related subsystems at $204 million. It will also support the detailed design and development of the polar orbiting platforms and platform servicing at $59 million; the power systems at $88 million; operations capability/utilization at $52 million; and management and integration at $133.5 million.

Program development activities

The $733 million requested for development funding is essential. Together with the initial funds provided last years, we will use these funds to conduct the detailed design of the Space Station, focusing upon hardware elements and systems.

The Space Station development phase comprises four major hardware-related projects and two major supporting development activities. Hardware development includes pressurized modules, assembly hardware/subsystems, platforms and servicing equipment, and the power systems for the core Station and platforms. Supporting development activities include operations capability/utilization and management and integration.

The design, development and production activities associated with pressurized modules provide the pressure structures and outfitting for the laboratory, habitation and logistics modules, the pressure structures for the resource nodes, the environemtal control and life support system, manned systems, and the components for the internal thermal control and audio/video systems. Launch package integration is also provided for these elements.

Assembly hardware/subsystems include the horizontal truss; outfitting of the airlocks and resource nodes; and subsystems in; propulsion; external thermal control; data management; communications and tracking; guidance, navigation and control; extravehicular activity; and associated launch package integration.

As noted before, the Space Station will utilize a 75 Kw power system, with power produced by photovoltaic arrays. The polar orbiting and later co-orbiting platforms will use photovoltaic arrays for power production and batteries for energy storage which are common with those used on the manned base. Space Station power system requirements include the design, development and production of photovoltaic power modules; common components for the polar platform power systems; the 20 kHz power management and distribution subsystem and components; and, flight, application and ground support software. Also included in the power system requirements is launch package integration.

The first of the supporting development activities is operations capability/utilization. In FY 1988, NASA is requesting $52 million for this work. In conjunction with the Operations Task Force recommendations, we will continue the planning of the operations structure for the Space Station and begin development of the top level plans and procedures for the utilization and operations phase of the program. The detailed design and development of the institutional hardware and software, exclusive of those items funded under the Construction of Facilities (CoF) budget, required to outfit operational facilities for support, training, and launch site ground processing are funded in this budget line. Utilization supporting development activities build upon the efforts initiated during the definition phase, and include the development of procedures, tools and equipment to fully integrate the user into the design and operation of the Space Station's flight and ground systems. User requirements and payload selection processes will also be developed.

Management and integration is the final supporting development activity, and includes systems engineering and integration (SE&I), data managment and information systems, program support, and safety, reliability and quality assurance. The SE&I activities will be managed by the Space Station Program Office in Reston, Virginia. SE&I activities include the establishment of design requirements, the development of integrated engineering models, systems engineering analyses, resource allocation trade studies, and the allocation of requirements among program elements. At the system level, SE&I will maintain key schedules and documentation, refine assembly and checkout logic, and establish interface verification and control requirements and procedures.

The data management and information systems activities will be a major program activity in FY 1988. In FY 1988, we anticipate significant TMIS capabilities will be added and existing capabilities will be enhanced. More functional areas will be supported, additional databases and applications will be developed, and we will expand the integration of TMIS capabilities with other Agency capabilities.

For FY 1988, funding is requested to enable NASA to implement the first, interim version of the SSE. This capability will be used immediately to support remaining work on the Space Station program requirements, preliminary design, and development of models and simulations. It is very important that the program maintain its SSE momentum during FY 1988 so that the program's extensive and diverse software efforts begin by using a common approach and foundation. The timely support of the program with the SSE capability is expected to produce significant cost avoidance in two primary areas. The first of these is the cost of producing safety oriented and carefully verified software to operate the Station. This will be a challenging task when you consider the software originates in widely diverse organizations.

The second cost savings is in the sustaining engineering of that software over the expected life of the Station.

With respect to the Space Station Information System (SSIS), our plans for FY 1988 are to continue the refinement of the SSIS. This will occur through adjustments to the presently baselined SSIS architecture and the specification of requirements into the systems that in turn comprise the SSIS. A key to our FY 1988 success will be continued close coordination with our colleagues from other NASA Headquarters organizations, primarily the Office of Space Science and Applications and the Office of Space Tracking and Data Systems. This activity will interact significantly with the PSC.

Program support will be provided by the individual NASA centers, and will include the management, technical and institutional support necessary to sustain the Space Station development activities.

Safety, reliability, maintainability and quality assurance activities will place an early emphasis on the development of criteria to perform critical design safety reviews at the black box and system levels. This criteria will be used to assess the proposed design of the Station during the preliminary design review. Quality assurance standards will also be established.

Flight telerobotic servicer

As noted above, Mr. Chairman, FY 1988 funding is also requested to continue the definition and preliminary design of the Flight Telerobotic Servicer (FTS). The FTS will be a highly automated telerobotic device used to assist in assembly and servicing operations. It will be capable of precise manipulations in space, and will operate with a mix of teleoperated and supervisory controls by the crew. The FTS program is being coordinated with the Space Station launch schedule, and is structured to provide phased capabilities based upon assembly, servicing and maintenance needs. Work will continue on the definition and design of the flight and ground systems and on requirements definition for an STS flight demonstration. The funding requested for FY 1988 is $22 million.

Operations definition

We must now turn to planning the ways in which the structure for conducting operations can be used in the development of flight hardware and ground systems. We must also prepare for the execution of actual Space Station operations beginning with the on-orbit assembly flights. Accordingly, we re requesting $7 million in FY 1988 for operations definition.

This request includes a variety of operations oriented study activities that are required to support the development of both flight hardware and operational facilities. Our FY 1988 activities will be concentrated primarily in the area of integrated logistics support. Using information generated as part of the development effort by the work package centers and the development contractors, specific logistics requirements will be considered and integrated in a structured manner into a program wide logistics support plan. Logistics support requirements must be defined early in the development phase and factored into the design and development of the hardware projects and the launch site in order to ensure an efficient design and reasonable life cycle costs. Our integrated logistics support activities include the initial establishment and analysis of logistics support requirements and the development of a maintenance concept. Other activities include studies of applications of automation and robotics to operations.

Transition definition

FY 1988 funding of $5 million is requested for transition definition activities, conducted in parallel with the Station development phase, to ensure that Space Station design will facilitate evolution to accommodate increased user requirements. The FY 1988 start will provide the minimum lead time required to demonstrate major new technologies prior to their incorporation in any evolving Space Station system. Transition definition studies will include mission and systems analyses to define evolution requirements, analyses to establish growth modes which optimize user accommodations, and technology forecasts to enable upgrades that will increase Station efficiency and productivity.

The objective of the initial systems studies is to review and understand options for Space Station evolution, rather than to define a specific evolution configuration. Systemic studies of the evolution options provide the knowledge necessary to (1) assures that the revised baseline Station design includes the appropriate provisions for evolution; and, (2) identify the technologies that must be developed. The evolution options are based on potential uses of the Station in the late 1990's and beyond. Options to be studied include an increased emphasis on research, on-orbit construction and launch of large systems, increased commercial participation, and potential new initiatives such as a lunar base or a Mars mission.

As an example of our evolution studies, let me cite a recent case which the Space Station program investigated the potential for the Space Station to support future manned missions. This year a special team conducted a preliminary analysis of the accommodation of future manned missions including lunar and Mars mission.

The preliminary analyses indicated that crucial technical experiments in the areas of life science, expert systems. ECLSS, and transportation must first be conducted. Our Space Station concept is an ideal laboratory to conduct these experiments. The Space Station would be an essential enabling capability for any manned mission of the future.

The budget requested for Transition Definition covers both the evolution studies and the early systems technology development. Evolution and technology development plans will be developed to enable a comprehensive program of evolution technology development for both software and hardware to begin in FY 1989. This planning process will be coordinated closely with the Office of Aeronautics and Space Technology. The integrated program will result in the development of high leverage technologies while the optons for evolution of the infrastructure are kept open for future decisions.

THEMES

I would now like to discuss our activities over the past year along the items of the dominant themes in the Space Station program.

Utilization

A basic objectives of the Space Station program is to ensure that the facility, as designed and built, will be readily accessible and responsive to the needs of the people who will be using the Station. This is such a straightforward, simple statement of intent that its ramifications may be overlooked. Nonetheless it has already had significant impacts on the Station design and operations planning.

During the definition phase of the Space Station program, the process of collecting user requirements began with the involvement of internal NASA program offices—the Office of Space Science and Applications, the Office of Aeronautics and Space Technology, the Office of Space Flight Operations, and the Office of Commercial Programs. These offices initially represented the three identifiable uses of the Space Station namely, scientific, technological, and commercial. An initial database was established and the design concept of the Station at that time was tested. Outside users were organized and consulted with on their requirements, leading to the formation of activities such as the Task Force on Scientific Users of the Space Station (TFSUSS), the Strategic Planning Group for Advanced Technology, as well as the Commercial Advocacy Group within the Space Station Office itself. These groups continued the oversight of requirements for the manned base and the platforms. They were also instrumental in obtaining the modifications to Station design. The changes in systems, such as power, can be directly traced to the impact of the users' requirements upon the design. The changes in element structure, such as the location of the pressurized modules, is directly attributable to user inputs.

The history of the polar platforms follow a similar pattern. The users' influence is clearly discernible here. In addition to the uses planned for the manned base, the platforms incorporate a fourth use—operational capability. The National Oceanographic and Atmospheric Administration (NOAA) is planning to use the polar platform and have added their unique requirements to the database. As the involvement of international users became clearer, and the European Space Agency studied the investment in a polar platform, an informal international users group was formed to assist in common platform design and operations. As additional users are identified, it is expected that this group will expand accordingly. Once the process of selection of the actual experiment and instrument hardware begins, a more formal structure will be given to this group, as well as to the users of the manned base.

During the course of our detailed definition studies, we have found that the concept of "functional allocation" in the Space Station laboratories is no longer necessary. Therefore, a separate "life sciences laboratory" does not appear in the current configuration. However, we recognize the importance of life sciences research and expect it to be an important and essential activity aboard the Station. In the development phase RFPs, we will request our contractors to insure proper accommodations in the U.S. laboratory for those life science activities which are compatible with other low acceleration microgravity activities. We will also ask our contractors to propose accommodations for those life science activities which are not compatible.

The emphasis on utilization depicted during the definition phase will continue throughout the development phase. I intend to assure the integrity of a facility that is first and foremost responsive to the user community.

International

The objective of significant international participation in the Space Station program, established by President Reagan at the outset, continues as one of our highest priorities. As we approach the initiation of hardware development activities in the United States, we are optimistic about the prospects of corresponding development activities being initiated by our partners: Canada, Japan, and member states of the European Space Agency (ESA).

The revised baseline configuration includes those elements to be provided by our international partners. ESA will provide the Columbus laboratory module, a polar platform and a Man-Tended Free Flyer. Japan will provide the Japanese Experiment Module while Canada will provide the first phase of the Mobile Servicing System. All of this, or course, is subject to completion of successsful negotiations.

Over the past year, substantial progress has been made in defining meaningful participation. As provided in our definition phase agreements with each of our partners. we reached program-level agreement last year on those program elements each partner would carry into preliminary design to form the basis for cooperation in the development and operation/utilization phases.

Our program-level agreement with the Canadian calls for them to perform preliminary design of a Mobile Servicing System (MSS). This will be used for station assembly and maintenance, attached payload servicing, deployment and retrieval activities and in support for extravehicular activity. On behalf of its member states, ESA is performing preliminary design on a Columbus pressurized laboratory module. Under the terms of the NASA/ESA program level agreement, ESA is also performing preliminary design on a polar platform primarily for earth observation. Additionally, ESA and NASA have recently agreed after a six-month joint study that ESA will provide a Man-Tended Free Flyer. Japan is performing preliminary design of a pressurized laboratory module known as the Japanese Experiment Module (JEM). The JEM consists of a pressurized laboratory plus an attached, exposed facility with a fixed manipulator and large scientific airlock. The Japanese concept also includes an experiment logistics module (ELM) for the resupply of JEM experiments.

Negotiations for the forthcoming development, operations and utilization phases began with each of the three partners this past June. These negotiations are proceeding at two levels. On a government-to-government level, negotiations led by the Department of State are proceeding to intergovernmental agreements to establish the political framework and legal regime for the program. NASA is supporting the Department of State in these negotiations. At the agency-to-agency level, NASA is leading the negotiations with counterpart space agencies and ministries to establish memoranda of understanding for the implementation, management, utilization and operation of the program. Consistent with our interagency review processes, a review of the government-to-government agreement was completed in January of this year and a new draft agreement based on this review was provided to the partners in early February. Following a round of negotiations with all of the partners, another interagency review has just resulted in a newly revised text which should form a good basis for resuming negotiations.

The Space Station is a civil endeavor. President Reagan approved the program on the basis of civil requirements—both scientific and commercial—and NASA, as a civil agency, will design and operate the Station complex. Because the Space Station clearly will be a national asset, we have consistently stated that the Department of Defense (DoD), like any other U.S. government user, might utilize Station capabilities. At present, DoD has identified no requirements for such capabilities. The U.S. Government's approach to the negotiations is simply to assure that options for using the Space Station for national security purposes consistent with out international commitments to the peaceful use of outer space are retained. I know of the Subcommittee's strong interest in this subject and wish to assure the Subcommittee of my strong personal conviction that the Space Station is and must continue to be a civil endeavor.

The negotiating approach of the United States is to establish in the agreements clear definition of responsibilities for the development phase with overall responsibility for the program resting with the United States. The agreements will also establish clear mechanisms for working relationships in the operational and utilization phase. A multilateral management mechanism is envisioned for this phase with fair and equitable allocation of Space Station resources and operational costs to all partners. We believe that through this process we can ensure that the United States will receive substantial benefits commensurate with its investment and responsibilities in the program. Our goal is to have all agreements in place as we initiate the U.S. hardware contracts later this year.

Operations

An essential part of the definition and development phases is to begin preparations for actual utilization and operation of the Space Station. We will put in place the facilities, systems, equipment, plans, and procedures necessary for flexible, user-responsive, and cost effective operation of the Space Station. In designing, developing, and planning operations for the Space Station, we must focus on the ways in which life-cycle costs can be held to a minimum consistent with safety and utilization goals. Our plans for achieving this utilization and operational capability will draw on the results of the definition and preliminary design studies as well as our work on life-cycle cost management and operations management concepts.

Mr. Chairman, in FY 1987 we will complete the definition of requirements for operational facilities including those needed for space and ground operations, launch site processing, and training. We have completed the definition of program-wide requirements for an integrated logistics support system. We have continued our work on life-cycle cost management and will report as requested to the full House Committee on Science, Space and Technology later this year. Before the award of the development contracts, we will submit to the Congress the results of new work in this area. The tools developed as a part of this effort will allow us to evaluate the effect of engineering decisions which will be made during the design of the Space Station on life-cycle costs.

Automation and robotics

The Space Station program is committed to the application of automation and robotics (A&R) in both flight and ground systems. Effective incorporation of A&R technology throughout the program will improve the effectiveness of the Space Station through increased mission safety and mission capability, while providing improved operational efficiency. The human-in-space will be more free to investigate his new frontier by entrusting daily operations of the Space Station complex to machines.

NASA has three primary thrusts in research and development which apply A&R across the Space Station program. The showcase in this area in the Flight Telerobotic Servicer (FTS). As noted earlier, the FTS will be a significantly automated device which will improve the efficiency and safety of Space Station related operations. The FTS capabilities could eventually evolve from relatively simple tasks to increasingly sophisticated ones.

NASA's second trust develops candidate concepts for a baseline capability in A&R for Space Station systems. Definition studies have identified optional capabilities which can be applied initially and then incrementally augmented during the Space

Station's growth through the use of "hooks and scars." The initial Space Station willl operate with significant levels of automation.

For the third trust, NASA plans to extend this baseline A&R capability throughout the Space Station's growth. This work identifies valuable targets of opportunity in A&R for the growth Space Station and applies them to the program through a process of technology development, demonstration, and application. The Office of Space Station and the Office of Aeronautics and Space Technology cooperatively fund the development of these growth A&R opportunities.

Commercial Development

The Space Station Program Office recognizes the potential for commercial participation in providing Space Station systems and services. By commercial participation we mean privately financed and developed Space Station systems which are incorporated into the program to satisfy user demand for Space Station services. The Space Station, as a multi-purpose facility designed to meet the requirements of a broad spectrum of users, is a research and development facility in space. Opportunities for commercial benefit are real but may be long term in nature. Great success by just one set of users, commercial materials processing for instance, could spur the demand for additional space facilities and resources which could quickly exceed currently projected available Space Station resources.

We recognize this potential and, consistent with government policy, encourage industry to consider participating in the program. We have: established guidelines for commercial participation that together constitute a statement of policy: signed an MOU with Space industries, Inc., of Houston, to exchange during Phase B information regarding our respective programs; and, included in the development RFPs, instructions to propose two plans to assist us in our efforts to promote opportunities for the commercial development of space.

The RFP requirement is important in that it prepares us for the future. The first plan required of the contractor is how the contractor will assist us in integrating a commercial element into the overall program. The second plan focuses on how the contractor proposes to stimulate U.S. private sector investment and involvement in the program. It is our expectation that just as the Air Force medium lift vehicle (MLV) procurement will undoubtedly provide a production base that could benefit the selected contractor in providing commercial launch services, the Space Station procurement could provide a techology base that could benefit selected contractors in providing commercial services on orbit.

Advisory structure

During the entire period of formalizing the definition of the Space Station, advisory committees have played an essential role, by providing advice and assistance that was unavailable from any other means. Under the auspices of the NASA Advisory Council, the agency has received advice from the standing advisory committees on space and Earth science, life science, and space systems and technology on how to get the most effective use of the Space Station. In addition, two task forces were specifically created to provide advice relevant to the Station: Commercial Use of Space; and Scientific Uses of Space Station. Various groups of the National Academy of Sciences, National Academy of Engineering, the Institute of Medicine, and the National Research Council have also contributed major studies. Particularly important has been the work of the Aeronautics and Space Engineering Board, the Space Science Board, and the Space Applications Board. Each has contributed major studies, either directed at the best ways to use the Station, or on such questions as the readiness of technology for use in Station design.

Fiscal Year 1987 is a year of transition for the work of such advisory committees, as the program shifts from the definition phase into the development phase. Although the problems we face are now somewhat different in the actual design and fabrication period, we continue to depend on the help we get from our advisors, and will do so extensively during the next several years as we get nearer to launch ana operations.

The NASA Advisory Council is about to organize a standing committee for the Space Station. This committee will look across the full range of matters pertaining to the Station, from uses to technical problems of design and construction and on to the interaction of Station operations with the transportation system. We expect to have subcommittees of this standing committee to consider various aspects of the program. The Congress has requested that the NASA Advisory Council examine how we should ensure early scientific return from the Station and how we should plan to operate the complex. My understanding is that Daniel Fink, the Council's chairman, has agreed to this request.

CONCLUSION

The FY 1988 budget provides the next rung of the ladder in our climb to a permanently manned presence in space. The Space Station program, identified as a key 1988 Research and Development initiative in President Reagan's recent competitiveness initiative, is an important vehicle to promote U.S. competitiveness in the development of technology and the conduct of science. NASA, the science community, industry, as well as the Congress and the Administration, have an opportunity to assure that U.S. competitiveness is well served in terms of the capabilities and opportunities afforded by the Space Station program. Collectively, we must assure that our individual roles are melded into a responsible "next logical step" for the American space program.

The Space Station program provides us with the opportunity to build on our accomplishments of the past and press on to our accomplishments of the future.

Senator RIEGLE. Thank you. Let me just announce for those in the room that might be interested, the major vote in the House just took place on a trade bill, the Gephardt Amendment was passed by a vote of 218 to 214. So I can imagine that there was some high drama there as they were closing out the voting period.

Mr. Myers, does anybody else have a formal aspect of a presentation to make at this point?

Mr. MYERS. I'm sorry, I should have made a point of that. We are prepared for answering questions, Mr. Chairman.

Senator RIEGLE. First of all, having gone through this chronology of steps, of reviews over a length of time and now leading to this revised baseline approach that you are presenting to us now, have we finished the process, is this it, or are you going to be back in four months or six months or twelve months and say look we have now finished our revised baseline two and we have a new plan and this is what the new plan is.

Or, and I want the best answer you can give me, have we finally gotten to the point in your view where we really know what it is we want to do? Has the President reviewed this? Have you sat with the President, has he gone through this, is this, are we really at a point where we have a definition and a package that is going to hold together here for the future, or are we still going through these phases?

Mr. MYERS. Mr. Chairman, we have done a tremendous definition phase. I say tremendous because I have been through program definitions many times, and we generally find that when you have started a program on the back of an old envelope you do not know what the costs are.

When you have done one-tenth of 1 percent of the program, which had been done at the time the $8 billion estimate was estimated, you do not have a grand and great confidence in it.

But we do have great confidence now in the price of this Space Station. We do have great confidence, we have had tremendously good inputs from the user community, and we have had some really outstanding work by our contractors in definition.

Now, having said that and having gone myself through a whole series of tries at what we could do to reduce the costs back down towards the $8 billion level, I think we have a program that is a very solid program. It gives us all the opportunities to grow that we can get.

The President has again backed this program. We do believe that although there is an NRC committee that is going to review the options again, I look at it as a great opportunity to give us confidence again in the costs and capabilities of this program.

Senator RIEGLE. Let me just ask you, has the President signed off on it?

Mr. MYERS. Yes, the President did approve our program. I have not seen the piece of paper myself Mr. Chairman, but the President has approved this configuration and we have had that approval come to us, and has specifically approved our going ahead with the Requests for Proposals.

Senator RIEGLE. Do you know the date of that approval?

Mr. MYERS. It was a few days before the third of April.

Senator RIEGLE. So it is your understanding then that the President himself, after a review, do you know who conducted the review?

Mr. MYERS. The review was led by the NSC, who are the people within our administration that bring together people for the development of space policy, and we worked very diligently and closely with them and with the Office of Space Technology, OSTP.

Dr. Graham and our combined final approach to the program was sent forward to the President and we received approval to go ahead with the RPFs.

Senator RIEGLE. So your assertion then to the Committee is that you are saying to us without any reservation that the President has reviewed it and made a final decision. This is the final program configuration decision and you are here to say we are ready to go, you are here to ask for the money.

Or is it something less than that?

Mr. MYERS. Mr. Chairman I have to say that this NRC committee that is going to be headed by Bob Seamans who was at one time the deputy administrator of NASA is going to review our program and look at some options. We are going to have a group at our Langley field operation working under the Space Station group under Tom Moser, review any other options that they would like to look at.

My own view is that we have done such a tremendously thorough review and analysis of the options available that I really have a hard time believing that they are going to come up with any changes.

For that reason we felt and agreed with the administration that we should release the RFPs because if there are modifications, we believe that they are going to be relatively minor.

Senator RIEGLE. What is not clear to me if we really are at that stage, what purpose of that review even serves at this point.

It seems to me, we are in a budget cycle too, as you know, and we are really at a very critical point in the budget cycle. We can not go back and change things that have already happened. But it seems to me that the requirement here of NASA and the administration is to, in effect, have the reviews completed by this point. So that coming in now in advance of the authorization process, you are bringing us in a sense final recommendations. Recommendations that we can hang our hat on, that we can defend, take to our colleagues, take to the country.

But what I hear you saying is that the NRC now is going to go over this again, maybe they will agree, maybe they will disagree.

Your hope is that any modifications will be minor ones. Maybe they will, but that introduces an element of uncertainty at a time when we are trying to be rid of the uncertainty so that we can make some decisions.

Has OMB signed off on this?

Mr. **Myers.** Yes, they have.

Senator **Riegle.** My understanding is, and correct me if I am wrong, that OMB has until the fall to make a final decision.

Is that not so?

Mr. **Myers.** The agreement that we reached was that the NRC committee would review the costs and the program content and would complete their studies by September first.

After that time, we, NASA and OMB and OSTP will review again where we stand as far as the 1989 and subsequent budget activities are concerned.

As I said, I do not believe that we are going to find major differences in the activity because of the tremendous definition program that we have already had. And even though there will be reviews of other elements, it is my personal belief that we are going to have the Space Station that we are proposing here.

Senator **Riegle.** Now are you saying then, when I asked the question about the President's sign off you were quite explicit about that.

I want to be sure that we understand each other about OMB. Are you saying as well now that OMB has gone over this, that they have signed off on this package and these numbers, not to say that there might not be some adjustment in the future, but that they are fully on board and that there is in a sense, whether or not there is a document signed by the President, he has given his approval, OMB has likewise given their formal and final approval on this?

Mr. **Myers.** What the OMB did and what we all agreed on is actually what happened.

We all agreed that we would set a schedule of funding for the program, define this configuration, go out to the industry for a request for proposal on the block one followed by block two. And in addition, ask for a proposal on this fully enhanced configuration, and ask the industry to look at what they could do to reduce the costs of their individual work packages.

We take all that input from the work packages in the summer and anything that comes out of the NRC in the fall and combine that for what we would go forward to OMB on the funding run out for 1989 and subsequent.

If there is disagreement, and we believe we are right, we will go back to the President.

But I really believe that we are going to find that unless I am wrong, very wrong, I believe that the definition work that has been done, and been very thoroughly reviewed by our people within NASA and within our committees, that I will be very surprised if there are major changes.

We all agreed that by putting out the RFP we were all agreeing that it would be a basis on which we could choose contractors, and therefore we were all in that same breath saying that we do not believe there will be major changes.

Senator RIEGLE. I hope you are right. This last year has been a year of a lot of surprises. I mean there have been almost more surprises than you can keep track of in this town in a lot of areas.

We always seem to get surprises in terms of cost estimates for exotic things, and this is certainly a very exotic project.

I do not know that I yet still have a clear answer to my question though. And that is what do we have in the way of a specific sign off from OMB today, what do you bring from them in terms of their stamp of approval on what you are asking for?

Mr. MYERS. They agreed to all of the elements that are in that letter that we sent to you Mr. Chairman.

That specifically calls out the block one configuration, specifically calls out the estimated cost for the program. It specifically calls out release of the RFPs for as I described them, the block one and block two, and then separately in an enhanced configuration. And that we will ask the contractors for reduced cost.

And that there will be an NRC review looking at a wide range of alternatives, and that we will review all that after their work in September as it affects the 1989 and subsequent budgets.

Senator RIEGLE. So they, at this point are they in agreement with you on what the figure is for 1988?

Mr. MYERS. $767 million.

Senator RIEGLE. And you are in agreement on that?

Mr. MYERS. Yes we are.

Senator RIEGLE. You have signed off on that.

Mr. MYERS. Yes.

Senator RIEGLE. But in terms of anything beyond 1988, that is still fluid.

In other words are you saying that they are endorsing the $14.6 billion figure over nine years or not?

Mr. MYERS. I can not say that they have endorsed that. They have allowed us to release an RFP which could very well come up with this kind of a cost. But they do want, this thing started actually Mr. Chairman by the OMB being shocked by our increase in price from the original $8 billion of 1984 to the number that we came in with on the total budget.

They at that time talked about an independent cost evaluation. They were not satisfied that we really had all our cost activities put together. We put a fairly large reserve in this program because of the problems that we had with the shuttle program.

They were not too happy with that, they thought we ought to have an independent cost review. That developed then into this idea of an independent cost review and a look at other alternatives.

I think we are going to have that with us, and I think OMB in fact believe that there may be some savings that come out of that. I believe there will be some savings that come out of the proposals that come from the industry.

Senator RIEGLE. But it seems to me if I understand it right, and I just want to nail this down, I do not want to take too much time because my colleagues are waiting themselves here.

I understand you to be saying that OMB has signed on a specific dollar amount only for the part that is in the 1988 budget.

Is that correct?

Mr. Myers. No. They agreed to 1988, 1989, and 1990. Because those are the run on numbers that we had in the original program. They have agreed with those, 1988, 1989, and 1990. I think beyond that it is up to us to review with the NRC and if they agree with us on this configuration, they will agree with us with the whole program I believe.

Senator Riegle. I am not persuaded that you have given what I feel we need to have in addressing my colleagues on the budget committee and the Senate as a whole, when they say to me, they will say to all of us, what is this thing going to cost.

Then we give them the ballpark number and they ask well is that a number that the President is committed to, is that a number that OMB has signed off on. You have given me a highly conditioned answer, which I in turn have to accurately give to them.

But that kind of an answer I think in this circumstance, with all the uncertainty we have had so far, I think is less persuasive to people who have to find ways to save money in the budget than if we had a much stronger assertion.

If we had a statement from the OMB director that he feels these numbers are solid, and that they are going to hold together, I just feel uneasy about how solid the ground is we are standing on here.

Mr. Myers. Mr. Chairman, I think there is a significantly important point here.

For this configuration, we, NASA have committed to that cost, and OMB has bought that cost if this ends up being the configuration. So what they are doing is they are saying we want the NRC to review this thing, we want to do an independent cost estimate and see if we agree with the cost estimates that NASA has made.

We are, I am personally very sure of our costs. We really put a tremendous amount of effort into that cost. We reviewed that with the OMB. They have agreed that that cost estimate is the cost that they would accept for the block one configuration. But they also want to have an independent cost estimate. They said that right off the bat when we first came over there with those costs.

So they will have that done.

I think we can stand behind that cost. I think we are talking about $13 billion for a development program, $1.6 billion additional for our basic laboratory and technology activity, giving this $14.6 that Mr. Stofan talked about, for the block one program.

I just think that is a very firm program.

And I would also say this. There will be a space program. The President continues to stand behind the Space Station. We will need that $767 million for the program that is in the RFP. I am sure of that. And if there are modifications I do not believe that they are going to be significant.

The only significant modification that could occur to me, would be if we sort of started with a clean sheet of paper or something. And if we do that, we are going to delay this program two or three years.

So I believe that we are going to come out with these kind of numbers.

And by the way, Mr. Newman points out I have been talking 1988 dollars when I talk about this. So there will be some inflation that occurs in the future.

Senator RIEGLE. Senator Kassebaum.

Senator KASSEBAUM. Thank you Mr. Chairman.

Maybe I missed your reference to this. How long before you contemplate block one being completed?

Mr. MYERS. The block one dates are, first element would be launched in March of 1994. We would have a man tended capability, where we could go up with a shuttle and dock with the Space Station and have the astronauts work on the station but then come back in the shuttle and come home, we would have that by March of 1995.

Then we would have a permanent capability, the capability to have men there permanently in early 1996.

Senator KASSEBAUM. And that is still part of block one.

Mr. MYERS. That is all block one.

Senator KASSEBAUM. Did you move towards the phased approach because you felt that it was fiscally more responsible or for scientific reasons, or why did you change the approach that had been contemplated?

Mr. MYERS. It was simply a more fiscally responsible position. We were embarrassed, I will have to say that I was embarrassed by finding, when we really went through a detailed cost analysis that our costs had gone up as much as they had.

We just felt that when you look at NASA's budget and the other threats to our budget that we have, that it was proper for us to constrain the program to stay within the budget projections that we had previously made based on an $8 billion program.

So we stay in the 1988, 1989, and 1990 budget levels to the same level we had previously projected. When we did that, then to get a reasonable date out here in the future it was proper for us to constrain to the block one approach what we would first build. That has decreased some of the power that we would have from 87.5 kilowatts down to 75.

It decreases somewhat the science provisions mounted, where we in this enhanced configuration had the science provisions mounted a long distance away from the pressurized module, and it decreased by taking off the solar dynamics program which is part of our extra power.

Those are things we felt we could do and still have a very effective space station, still launch it with the shuttle and still have an opportunity to grow eventually in the direction that we want to grow.

Senator KASSEBAUM. That was one of the questions I was going to ask. With that reduction in power, did you feel you were going to lose any science capabilities or that our partners might have some concerns about it?

Mr. MYERS. There has been a lot of speculation about that. Our studies would show that if all the things that we have estimated are brought together in the station and if we operated as we had planned to operate them, we would eventually end up with this 87.5 kw requirement.

I have been having a little trouble with that because I went through the Skylab program, and you may remember that we lost one wing off the Skylab in the launch period. So we reduced by 25 percent the power that was involved on board. We ended up using just as little over one kilowatt for our science programs. We had to manage a lot. We had to work around some problems, but we only used about 1.2 or 1.3 kilowatts for the science part of the Skylab program.

We are talking here with 75 kilowatts, we use about 30 for housekeeping, and so we would have 40 kilowatts available for the science and for the material processing and all the things we will do on the space station.

It is really a major increase. It is much more than the Russians have, and it puts us, I think, in a position where we can put some real power into our material sciences where we need a furnace, for example, and still put ourselves in a position where we can supply our European and Japanese partners very well, very adequately.

Senator **KASSEBAUM**. I just have one other question, Mr. Chairman.

I do not like to take worst case scenarios, but you mentioned that these were 1988 dollars. Do you think it would not be wise to factor in some inflation growth so it would be a little more accurate?

Mr. **MYERS**. I would like to ask Mr. Newman to answer that.

Mr. **NEWMAN**. The budget we present will be in real year dollars. We will ask for the amounts in the year that we require it. We have, in fact, stated the estimates——

Senator **KASSEBAUM**. So in your out-years, you have factored in an inflation increase?

Mr. **NEWMAN**. In our negotiations with OMB and in the amounts we request in fiscal year 1999 and subsequent we will build in the appropriate inflation that we recognize at that time.

Senator **KASSEBAUM**. This figure of $14.6 billion reflects that?

Mr. **NEWMAN**. No, that is in 1988 dollars. That does not reflect the projection of future inflation.

Mr. **MYERS**. I guess my problem with that is that we have always had difficulty trying to guess what the inflation is going to be.

Senator **KASSEBAUM**. So does everybody.

Mr. **MYERS**. So NASA normally lists their programs in the now-year dollars but for each year in asking for each year's budget we ask for that portion of inflation associated with that. That has been kind of a standard for our history. We could give you an estimate.

Senator **KASSEBAUM**. No. That can be a rude awakening, however.

Mr. **MYERS**. Yes, for long programs particularly.

Senator **KASSEBAUM**. That is right.

Mr. **NEWMAN**. With the inflation factor that we have applied, the $14.6 billion would come out to about $17.7 billion, but that is based on future projections.

Senator **KASSEBAUM**. Thank you, Mr. Chairman.

Senator **RIEGLE**. Thank you, Senator Kassebaum.

Senator Adams.

Senator **ADAMS**. I am curious about the Russian launch. Do they use expendable launch vehicles for all of their work at their station?

Mr. **MYERS**. So far.

Senator **ADAMS**. We do not, of course, know what their future plans are, but they are in space and with a space station and capable of doing additional launching.

Why is it that we do not use expendable launch vehicles to put up basic materials so that we are not held up by the shuttle program?

Mr. **Myers**. In this activity we are doing with the Air Force, looking at a heavy lift launch vehicle, one of the elements of that study is the possible use of a heavy lift launch vehicle for that purpose.

We also have looked at the use of a heavy lift launch vehicle for the assembly of the space station as a way of reducing the number of shuttle flights in that time period and also as a means of launching larger assembled portions of the space station.

Senator **Adams**. You have looked into it, or is that part of the program?

Mr. **Myers**. We are looking into it. It is not part of the program. The heavy lift launch vehicle is just a study, and we are going to be studying that with the Air Force for probably the next year before a decision will be made on the development of a heavy lift launch vehicle.

Senator **Adams**. What is the difference in cost and time? It is going to take you seven years to get up there at the present time, I gather, at a minimum, or 1996, which is really nine years, and they are already there.

What is the difference in timing and cost if you used the shuttle only for what is necessary in the manned area and used expendable launch vehicles as the Russians have done in order to put their major components in space?

Mr. **Myers**. One of the problems is that the heavy lift launch vehicle does not exist, and if that heavy lift launch vehicle is approved and came on line in 1993, we have had some preliminary studies that indicate that we could save about six shuttle launches by launching the space station with a heavy lift launch vehicle, so there would be an opportunity there.

One of the portions of that study is going to be to look at that activity.

The heavy lift launch vehicle could also be used, Senator Adams, for some of our planetary missions because we are strapped right now in making direct shots at the planets. We are having to do all the trickest trajectory operations possible by going around Venus, back around the earth twice, and off to Jupiter with the Galileo. That turns out to add about three years to the flight time, three or four years I think.

Therefore, the scientists that are looking for that tremendous opportunity from Galileo are going to be delayed. If we had a heavy lift launch vehicle, we could take a direct shot at these planetary missions.

Senator **Adams**. Can you buy them elsewhere?

Mr. **Myers**. Excuse me?

Senator **Adams**. Can you buy the lift elsewhere?

Mr. **Myers**. Well, the French are building or are in the process of designing a heavy lift launch vehicle that will have about the same capability as the Titan IV. The Chinese have a fairly big launch vehicle. The French are moving in that direction, but they are a long way away, too. I think the Russians are probably closest.

Senator **Adams**. I have no further questions, Mr. Chairman.

Senator **Riegle**. With respect to the understandings, the discussions that have been going on with our international partners with the space station, we have had this controversy with the Defense Department or people somehow expressing a defense point of view coming in and at various points putting those discussions or putting those negotiations with our international partners in a very awkward spot.

Now, we are told that things have finally been sorted out. I would like you to be very specific. Where do we stand today?

Mr. **Myers**. Well, I think things are sorted out, Mr. Chairman. We have now reached agreements that really protect all the interests of the United States, including the civil space station. The opportunity exists to go ahead with the negotiations with the Europeans and with the Japanese. We are starting, as a matter of fact, tomorrow in our negotiations with Canada.

Basically, it boils down to following the position that the President originally had of a civil space station that will be offered and has been offered to international partners to work with us.

You know, the DOD originally showed no interest in the space station. They had no interest in the space station. On the other hand, we have always had experiments for peaceful purposes on the shuttle program and in space labs, and we sort of figured sooner or later they are going to want to use the space station.

Well, it turned out they came on very strong in January with the idea that they had to have an extremely strong position on this, and we now have worked it out to where the use of the space station will be within all the treaties, international treaties, for the peaceful use of space and that the DOD, if they want to use the space station, will be able to use it within those limits and will pay for the use of the space station.

Senator **Riegle**. Is that agreement in writing?

Mr. **Myers**. Yes, it is in writing.

Senator **Riegle**. Is there a written statement now within the administration that nails this down or not?

Mr. **Myers**. Yes, there is. It is called the International Governmental Agreement, and it is the basis that our people use for negotiation with the Europeans.

Senator **Riegle**. But in terms of this late arising interest from the Defense Department that put this in limbo for a while, are those issues settled in terms of a memorandum now that exists that would address meetings that were held or the summaries of meetings that were held, and which would state the conclusion that this debate is now over and settled within the administration?

Mr. **Myers**. I do not think we have a written track of all the meetings and everything, but we do have an agreed-to set of documents that are used for negotiation, and they are certainly available for members of the Committee. We could brief you on them or have the State Department do so.

Senator **Riegle**. It is the product of the settling of this disagreement?

Mr. **Myers**. Yes, sir.

Senator **Riegle**. Has the Secretary of Defense signed off on this?

Mr. **Myers**. Yes, the Secretary of Defense, the Secretary of State, and NASA have all signed off on them, and they are the agreed basis for the negotiations.

Senator **Riegle**. Is that another way of saying that we do not have to now worry about this issue arising again in 30 or 60 days?

Mr. **Myers**. You do not have to worry about the issue arising again. You have to worry about the fact that, personally, I think there was damage done in the discussions with the Europeans because of the delay and then another delay. So I have to worry about that.

Now, we have another issue with respect to the Europeans and the Japanese that deal with issue of the command of the space station.

Senator **Riegle**. Let me come to that in a minute. I want to make sure that we really finish the issue on the defense dispute here.

So the Department of Defense has signed off on this. You now have a firm understanding. Space station is going to be used within the international agreements that are pre-existing. That appears to be satisfactory to our partners, our international partners?

Mr. **Myers**. I cannot say that it is. We really have not started that negotiation yet. I know that the partners, all three members, have agreed to continue the negotiations.

Senator **Riegle**. So when will we have a sense for when we are over that hurdle?

Mr. **Myers**. That is a good question. These negotiations are hard negotiations, Mr. Chairman. There is a lot besides that DOD issue that is involved.

The general management of the station is still at issue. That, we have not yet negotiated. The partners feel very strongly that they should have a strong say in the management of the program. We take a very firm position that we must be in charge in flight and we must be in charge of making sure that the overall program is safe and effective and efficiently operated and that we are going to make sure of that.

So we do have that yet to negotiate with them.

Senator **Riegle**. Could you just review for the record just briefly the cost sharing arrangements as they have tentatively been marked out?

If you take, for example, the $14.6 billion figure, how much of that are our partners intending to put up of that, if any, or if they are not putting any of that up, how much are they putting up to augment that?

Mr. **Myers**. I would like to have Mr. Stofan deal with that question.

Mr. **Stofan**. The contribution of the partners at the present time, you have to realize where they are. They are just in their phase Bs, where we have finished it, and that is when we found out we had a cost growth. They are still in their phase B process.

The amount they contribute depends on the exchange rate of the dollar, but in dollar terms as of today, their contribution is going to be: the Europeans, about $2.5 billion; the Japanese, about $2 billion; and the Canadians about $500 million. This is for their elements that they will deliver to the station.

Senator RIEGLE. Now, that is over and beyond the $14.6 billion?

Mr. STOFAN. That is over and beyond that. That is right.

Senator RIEGLE. As I have looked at the configurations, the money they would spend builds their module that will connect onto the U.S. portion of station; but in terms of their contributing money to the basic superstructure, we are footing all that cost.

Mr. STOFAN. Yes, we are footing all that cost.

Senator RIEGLE. So it seems to me in a sense if we were to divide up command control—I do not suggest that we do this, but if we were going to divide it up based on where the money was coming from in total, it looks like we would have a pretty good share of the command control because we are putting up the lion's share of the money. Is that correct?

Mr. STOFAN. Yes, that is right. We have looked at this, the management concept as being one of a corporation where they are our partners but they are junior partners, and there is a chairman of the board, and there is a corporation, and that is us. We have taken that position, I think, quite strongly and will in the future.

Again, they will contribute less money, and they will provide a capability. Our proposal, what we are trying to negotiate into the agreements, is half of the European module is for our use, half of the Japanese module is for our use, and the Canadians will receive some percentage of the science use of for what they are contributing in their remote manipulator system.

Senator RIEGLE. Do the partners get some percentage, a reciprocal percentage of our modules?

Mr. STOFAN. No. Our module is all ours. Our platform is all ours. Their platform is theirs, and right now we are proposing half of their module is ours, half of the Japanese module is ours.

Now, the Europeans also want to use a man-tended freeflier in conjunction with the station. The use of that comes out of their resources that they had for their module. If they came along and wanted to use it, we said fine, as long as you stay within your original resources. You do not get any more. So it does not affect any of the other partners.

Senator RIEGLE. So one way to view this might be to say that we are proposing that we would have half of the use of the modules of the Japanese, say, is in effect it represents they're sharing their module with us because we are bearing the superstructure cost of putting the whole arrangement up there?

Mr. MYERS. That is correct.

Senator RIEGLE. Does it look like we are proceeding along quite well in these discussions, or is it too early to tell whether——

Mr. STOFAN. Along those lines we are proceeding quite well. I think Dale had mentioned the point is that the management concepts are the ones that are going to require more work.

I think, though, there is a solution to that. The management of the space station is in different elements. The management of the core station we talk about is where the corporate structure is. They can have complete control over their polar platform. They also have total, complete control over their man-tended freeflier.

So I think the different elements will be managed in different manners, and I think we will be able to work our way through that.

Senator **Riegle**. Is it fair to say that it is clearly understood within our own government that NASA has operational control of the space station if and when we get it built?

Mr. **Stofan**. There is no confusion on our side that that is something that is a must and it is something that we will not negotiate away, the control of that space station.

Senator **Riegle**. Within our own government now?

Mr. **Stofan**. Within our own government there is no confusion on that whatsoever.

Mr. **Myers**. We have never veered from that position.

Mr. **Stofan**. And will not.

Senator **Riegle**. I think it is very important that you hold to that position, and I would insist just as fiercely, as it sounds as if you intend to, that it has to be that way. If we are going to go up there with a civilian space platform and for peaceful uses and we are in an international consortium arrangement with others on the basis of the same understanding, I think it has to be absolutely clearcut that this is a civilian operation and that the center of control and command has to be in our civilian space agency, and properly so.

So if there is ever even a shadow or indication to the contrary, I would expect you to alert us immediately.

Mr. **Myers**. We certainly will, but I think that is one thing you will not get alerted on because we feel very strongly about that.

Mr. **Stofan**. I think with the internationals we are trying also because they are putting up an appreciable amount. In their countries, this makes up a very large share of their space budget. We are trying to give them the maximum autonomy that we can over the use of their resources but yet retain the overall management of the space station so it is run in a safe and efficient manner. We are trying to balance these two things.

Senator **Riegle**. I think that is a reasonable way to do it.

Let me ask you for the record to indicate why you feel that the international blending in partnership is important here. What is to be gained by going that direction?

Mr. **Myers**. Well, certainly we end up with another contribution on the order of $5 million. We have had very good international science activities in the past. We have had excellent relationships with the Europeans, and we see that same science basis with the Japanese.

So I think it is a place where we have always found that it is another indication of international cooperation, that in the science area has been extremely valuable. And so we look at it as another opportunity to do that, just as we have often had joint programs in science.

Senator **Riegle**. I would just augment your answer by saying that we are in a world that is filled with tension at the best of times, and that the promise of moving off the planet, moving out into space, is something I think captures the imagination of all people around the world.

And I think if we can demonstrate our ability to work cooperatively in a joint venture with other nations, that we perhaps have a setting in which we can prove some things about human nature and our ability to work together that we sometimes have difficulty demonstrating here on Earth.

And it seems to me that, both for reasons of financial burden-sharing and efficiency of the use of resources, but also to learn better how to work with one another in complex endeavors of this kind, that there is a great value in having this be an international effort.

And of course, some people have suggested that in terms of a later flight to Mars, that maybe we ought to think about doing this even with the Soviet Union, on the theory that this would be a benign setting, where perhaps two countries that have many problems between them could maybe find some way in which to learn perhaps how to understand one another better and cooperate together.

But not sort of leaping quite that far here, it seems to me that the international dimension of this is really one of its most important parts, the fact that I think mankind, humankind, if you will, has a common interest in wanting to be able to learn what is to be learned by taking this step off the planet out into space.

The scientific and research gains that are to be had ought to be, I think, available in some reasonable fashion to everyone around the Earth. And so I would hope that we could stay very much on the track of trying to develop an authentic and sound international cooperative dimension to this.

I think it adds importantly, and I think as we have a chance to talk it over as a nation with ourselves and as this whole program and its potential has a chance to become better known by the American people, I think the fact that there is this international dimension I think most people in this country will find to be maybe one of the important features.

That is just my judgment, and time will tell. But I think most American people would see wisdom and value in that. I think it helps make this something that the public may be more interested in wanting to do.

It may help with the general support level of the space station itself.

Mr. **Myers**. Mr. Chairman, that is an excellent point and I am sorry I did not bring it up myself. As you know, those who fly on the shuttle and look down at Earth see the world as a place where it is almost an imperative that we cooperate.

And there are those, certainly those great opportunities that are ahead of us.

Senator **Riegle**. You know, just as an aside—I do not want to dwell on this in any great length, but were you around, Mr. Myers, when we did the docking with the Soviets years ago?

Mr. **Myers**. Yes, I was.

Senator **Riegle**. You know, looking back now at that time, one wonders and even marvels about the fact that there was a basis in discussion and dialogue that led to the decision to attempt to do a very complicated feat jointly in space, one that put cosmonauts and astronauts in jeopardy, if you will, together, depending upon each other for the success of the venture.

And yet, somebody had the vision to conceptualize doing it, to work it on through. It happened, it was successful, and I suspect both nations were the better for it.

Somehow we have managed to get off that track and onto different tracks. But I am struck by the fact that in modern history, within a relatively short space of years, within your own professional, operational lifetime in the space program, we were able to carry on ventures of that kind across international boundaries and despite other differences and so forth.

It would seem to me that if we could do it then, we could do it again.

Mr. **Myers**. You know, both sides had an incentive to do that, I think, and that is important. We must be in the position that the two nations really want to work together.

As you know, we just recently signed an agreement with the Russians for an exchange of science data, and we think there is at least a beginning again of this odd kind of almost independent of politics interest in working together in space.

Senator **Riegle**. Well, one thing about it. I mean, I would rather go down that path than down the Star Wars path, just speaking as one person, one citizen, one Senator.

But it seems to me that the Soviets have been inventive. They have managed to get out into space. They have a manned space station up there. They have done some things that are to their credit.

And we have had an extraordinary record in space. We have sent out people to the Moon and back and a host of other things that have been startling national achievements.

Their curiosity and interest in moving out and attempting those feats and our own it seems to me does reflect something in common. I think their quest to learn and to challenge themselves in outer space and ours, there are some similarities there.

So you know, I think there is some basis in that kind of questing spirit, that we ought to find some way perhaps to do more with.

Let me just say, I am going to have a series of questions that I am going to submit to you for the record [1] on the phase two program, where I want as much detail as you can provide. And I will give you a very clearly defined format for what I am looking for in a number of areas.

And also, I am going to be looking for more detail and as much detail as you are able to give us on the block one part as well.

I am going to give you, in addition, some questions that relate to the requests for proposal phase that you have now just entered into. I think it is important that those requests be out there. I see that as a sign of progress.

I have had the occasion over the weekend to go out and look at the mockup of the modules that North American Rockwell has constructed to scale. So I was able to actually get inside the mockup of what it is that we propose to do here.

And it certainly was useful in terms of my own understanding. But I think as I looked at what is required in terms of the manufacturing capability and everything else to be able to be in a position to move to get this done, that it is very important that we continue to move ahead with the process.

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[1] See p. 431.

So that this is not just ideas that are spinning around in somebody's head, but that serious people can apply their professional talents and we can start to do the engineering, do the advance work, start to create models, do things, build this thing, and get going.

So I will have a series of questions for you in that area, and I would like you to be as specific as you can in that regard.

Mr. **Myers**. We certainly will be.

Senator **Riegle**. I am also going to give you some additional detailed questions in the area of the power plans for the station. It seems to me that we do not want to go below 75 kilowatts, for starters.

I think there was talk that that might be the case, and I feel very strongly that we have got to have, as I know Congressman Boland does, that we have to have enough power up there to do things. And we should not kid ourselves about that. So I will have a series of questions for you in that area.

I am also concerned with respect to our space science program, and there is a lot of frustration, as you know, because of the accident pushing things back and other things that have impinged, that have really set back the space science program.

And we have a lot of things that space science professionals are waiting to do, feel a strong need to do. So I will have some questions for you as well in terms of a number of specific issues in the area of space science as it relates to what is seen here.

The same thing with respect to advanced technology. I will have a series of questions in that area that I am going to ask you to speak to.

Let me just raise one other thing specifically here, and that is, you know, we have gone now to block one, block two, and I suppose you could do this a lot of different ways. You could have five blocks, you know.

It has been cut a certain way and the body of thinking obviously came down with the notion that block one has to be of this general configuration and then you go from there. I do not want to open this thing up, but I want to ask a conceptual question and I would like you to give me the best answer you can.

If we were to try to take block one and cut it into two pieces, with the theory in mind of trying to get something up there sooner, if someone posed that question could we take and, using the building blocks concept, have the initial building blocks be smaller in scale, but be something that perhaps we could do sooner, so that we could get moving at a faster rate? Are we at a point here where we have squeezed this thing down now to the point that this is sort of the minimum amount of critical mass that you need for block one and therefore the timetable is just about as short as you can possibly conceive it being?

Mr. **Myers**. Yes, we looked at a whole series of different configurations, seeing what we could do to squeeze it down. We really had as our objective trying to take this thing back down to the $8 billion that had originally been estimated for it.

So we really did look at elements that would be sort of minimizing the configuration. And the problem that we get into is that any time you get a couple of modules together and a boom to start working to where you can handle scientific experiments, you end up with a lot of integration work.

And when you do that, to assure yourself that what is going to go into space works in space, there is a lot of testing on the ground. And we may be somewhat conservative now, possibly because of the Challenger accident, but we do not see how we can really get ahead of the schedule that we have, which is March of 1994 for first launch.

Remember, that is constrained by the dollars in 1988, 1989, and 1990. You could do somewhat better if you had an unconstrained budget, but not a lot.

I have heard numbers where people have talked about the strong desire to get into space by 1990 with something, and there is just no way that can be done. That is three years from now.

And we do not know how to do it and I do not think anybody else in the world knows how to do it.

Senator RIEGLE. If there were more to work with in terms of that cost buildup on the front end?

Mr. MYERS. It would help. We could probably get into the earlier year if there were more money.

Senator RIEGLE. You are saying maybe it buys you 12 months?

Mr. MYERS. I think really probably six to nine months is about as far as we would imagine we could bring it.

Senator RIEGLE. I am not sure that cost premium, if that is the time that you buy—you know, that does not sound to me like it buys you much.

Mr. MYERS. Well, I think we really have come out with a good program, Mr. Chairman. It is a judgment factor, of course.

And we are driven by our friendly competitors in Russia, certainly. But I would rather have a space station that has some unique capabilities, like we have in this space station, than to copy what they have.

We really do have some advanced technology that is going to be important to the future in terms of the closed loop environmental control system, in terms of the internal power system that we have in the station, in terms of the data transmission system.

These are all real moves forward, and I would rather do that right than to crash into getting something out there, in spite of the terrible trauma that we have caused to our science community and to all the other elements of our programs.

Now, having said that, I am also working on Mr. Stofan all the time to reduce the number of launches of the shuttle required each year, so that we can make more shuttle flights available for science. So we will keep working that, too.

Senator RIEGLE. Well, I tend to agree with your thinking with respect to the fact that we all want to get this done as rapidly as we can. But I think everything argues for being very measured about not kidding ourselves as to how long it takes, and to make sure that what we are doing is being done right and that we are doing the scale of operation that really becomes the foundation that lets us move off into later steps down the line that we might not even fully imagine right now.

So it seems to me it is a very powerful and dramatic moment in human history, it seems to me, if we can succeed in taking ourselves up off the planet in a permanent work station setting, a research center, as you say, with unique properties that allow us to expand our level of knowledge in ways that we cannot possibly do here on Earth.

I think to conceptualize that step and to take that step is a very significant development in human history, and I am not sure yet that it is very clearly understood in a broad public way, because there has not been much debate about this.

And we are having a hard time right now with things right here on Earth, for people to be able to spend much time thinking about it.

I will just finish by saying, I do think it is very important that the scale of what we do be proportional to not only what we want to achieve, but what that has to then become the foundation for in terms of later work.

And I for one would feel that we are better off having to live with a somewhat extended timetable if what we are doing is sensible in terms of the overall design and meaning of what it is we are setting out to do.

Obviously, our international partners have an equal stake in that and have some voice in that as well.

Well, thank you for your testimony today, and we will have those questions for you for the record.

May I now ask Dr. Black and Dr. Banks if they would come to the table once our witnesses have left the table.

Mr. MYERS. Thank you, Mr. Chairman.

Senator RIEGLE. Gentlemen, we are delighted to have you here. We have a vote starting on the Senate floor, and that may be followed by subsequent votes. So we are going to be very compressed for time here.

I am going to ask each of you, if you can, we will make your full statements a part of the record. Our first session ran longer because there was so much interest by colleagues in it, as you saw.

And then I ask each of you to make about a five minute presentation. I am going to hold you to that, because I want to hear it and we are going to run out of time.

So who would like to begin?

STATEMENTS OF DR. DAVID C. BLACK, CHIEF SCIENTIST, OFFICE OF SPACE STATION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; AND DR. PETER BANKS, DEPARTMENT OF ELECTRICAL ENGINEERING/SEL, STANFORD UNIVERSITY

Dr. BLACK. Mr. Chairman, thank you for the opportunity to speak to you this afternoon.

I think the points I would make by way of introductory remarks is to remind you and the record in this case, as the rest of your colleagues are not here, that the space station is a multi-purpose facility.

It was designed to address a wide range of national needs and to serve a variety of users. Included in that will be the science users, for which of course we are here today, the technology and commercial users.

The space station is not really justified solely on the basis of science, but in fact can be, as I think you will hear and the record will show, an extremely valuable device for the conduct of space science. And it really should be viewed, as I see it, not as an isolated device, but rather be viewed in the context of a broad thrust to conduct space science in this nation.

The space station program really has a variety of research modes, and you heard about some of those earlier this afternoon, one of those being the unmanned platforms. And I think it is important to stress that the space station is not just—the program does not involve just the manned program, but also involves a very significant and extremely capable component of an unmanned program, and that is where the platforms come in.

In addition, the attached payload capability, which was discussed here, taking advantage of the truss structure, enables in fact, I think, a very fundamental way of doing space research, something which is often termed as "quick is beautiful."

It is taking advantage of the opportunities presented by having a permanent human presence in space, as well as the facility of the character of the space station permanently on orbit. And I think a creative way can be found to use that capability, to help shorten in many ways some of the tremendous delays we see in space research opportunities presently.

Of course, finally the pressurized modules, which in a way fundamentally enable a whole new class of research, what Peter and I have referred to as science in space, and this is the laboratory kind of capability for the experiments rather than the observational capability.

Here we see a true quantum jump, and I think one of the frustrations has been often that it is difficult to say with specificity what might come out of this capability.

But in many ways it is like the Hubble space telescope for astrophysics: It is not so much what we know will occur with that, but it is the discoveries that will occur, unknown discoveries, when you have this tremendous increase in capability.

And for the microgravity research we are in much the same area. We have here a tremendous increase in capability, and the real exciting things are going to come from things we cannot here today predict.

To conclude, I think that the important point was one that was touched on by Mr. Stofan in his remarks. The space station should be viewed not as a unique short term mission, which is what NASA and this nation are used to seeing in terms of our space research activities.

It is a long-lived research facility in space, and as such it is often difficult to say what will this do. When you build a new research laboratory at a university, for example, what you know is that it will be used, for example, for genetic engineering and that sort of activity, and that is the level of detail you go into.

All you really know is you are enabling a fundamentally new research capability in many ways. I think that is the way we have to start looking at the space station.

Finally, although Senator Adams is not here, I think what he would find, unlike his statement—and I was a bit surprised by that—I think he will find that the space station design does in fact meet the requirements of a wide variety of the science community, because that community has been involved from the very beginning in defining what it should do.

And in fact, as was pointed out, it does specifically meet the launch requirements, as well as many of the more important fundamental research things that must be done if we are going to undertake the manned mission to Mars as precursor activities.

That concludes my opening remarks.

[The statement follows:]

STATEMENT OF DAVID C. BLACK, CHIEF SCIENTIST, OFFICE OF SPACE STATION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and distinguished members of the subcommittee, thank you for this opportunity to discuss with you the Space Station program from the perspective of the likely scientific users of the Space Station. The Space Station with its manned base and unmanned platforms constitutes a significant capability for the scientific community and I wish to discuss some examples of that capability for a number of the scientific disciplines that will use the Space Station. I will comment on some of the concerns that have surfaced in response to the recently announced plans to undertake the Space Station program in a phased approach. I also would like to remark on the role of Space Station platforms, and on plans for preparatory research for Space Station.

When I testified before this Subcommittee last year I remarked that the Space Station, properly conceived, would be a valuable national asset, one that could contribute significantly to the nation's research base. My views on this point have not changed with the passage of a year. The baseline design that emerged from the Phase B studies and modified by the Critical Evaluation Task Force is one that is very responsive to the requirements of the potential users of Space Station. Indeed, many of the changes in design that led to a part of the increase in estimated cost of Space Station are direclty traceable to user requirements. Allow me to cite some representative examples of how the Space Station that we are currently contemplating could benefit scientific users of the Station. It is convenient for the purposes of these remarks to place likely uses of Space Station into one of three categories; pressurized volume research, attached research, and platform research.

The Space Station platforms constitute a major capability for the conduct of what are usually referred to as the unmanned space sciences. This involves the disciplines of astronomy and astrophysics, earth sciences, and solar-terrestrial to name a few. The platforms will incorporate a highly modularized design concept, building on the Multi-Mission Spacecraft design that was so successful with the Solar Max Mission and which is the spacecraft for the upcoming Gamma Ray Observatory and for the Upper Atmospheric Research Satellite. The capability of the platform system is such that it can readily meet the requirements of multi-instrument synergistic payloads such as the polar orbiting Earth Observation System (EOS) or of a single facility-class instrument such as the Advanced X-Ray Astrophysics Facility or the Space Infrared Telescope Facilitiy. These payloads could become potential platform payloads once they become approved projects. The platform that would support the latter two examples would fly in a low inclination orbit similar to that of the manned base of the Space Station. The Space Station platform is a highly flexible yet capable system that should provide low-cost, high-performance spacecraft for the disciplines mentioned above as well as others that normally do not require a high degree of human interaction.

The importance of Station platforms to space reserch is recognized also by our international partners in the Space Station program. The European Space Agency (ESA) intends to provide a polar platform that will operate in a synergistic manner with the U.S. polar platform.

An area of research that, in my view, has not yet received adequate attention is that which can be conducted by instruments attached to the superstructure of the manned base. Because the Space Station offers a much higher level of resources continuously on orbit and because it will permanently manned the potential of using the manned base for a variety of research activities is indeed high. For example, there are plans in the solar physics community to attach a high resolution solar observatory to the manned base. There are plans in the planetary science community to attach an astrometric telescope facility to the manned base. The former instrument would provide the highest quality high-resolution studies of the Sun yet available, while the latter would provide the first comprehensive search for and characterization of other planetary systems. Because of the low inclination orbit of the manned base the Earth-viewing instruments are designed to study primarily the tropical regions. Specific emphasis is on monitoring rainfall in the tropics as that is one of the dominant factors in controlling the Earth's hydrological cycle.

A particularly promising aspect of attached payload science lies in the area of what is referred to as "Quick is Beautiful" research opportunities. This is mode of operation that is intended to reduce significantly the time from inception of a research concept to flight and possible reflight of modest-scale instruments. The intent is to find a way to increase the number of individuals that have actual space experimental experience and to match the timescale for space research more closely with that which is typical of a graduate student's thesis research. The Space Station, because of its permanent nature and the continuous availability of crew, could well provide an innovative way of addressing this major problem in the health of the nation's space science efforts.

If there is any single area in which the scientific potential of the Space Station is most evident, it is in the area of research in the pressurized volume that the Station will provide. Here, the Station fundamentally enables an entirely new class of space research, that of doing science in space rather than just the science of space. Research in the pressurized module will be fully experimental in nature as contrasted with the observationally oriented space sciences.

The major scientific disciplines to benefit from the Station modules will be the life and material sciences as well as some research in the areas of basic physics and chemistry. Key resources that the Station will provide involve power, time on orbit, and human crew.

Much, and in many cases to much, has been said regarding specific advances that will come in these scientific disciplines as a consequence of the Space Station. In my view it is very difficult to say with certainty which specific major advances will occur. However, just as with any major advance in capability (e.g., the Hubble Space Telescope in astronomy), one can be certain that major discoveries will follow once the facility is operational and people began to think creatively as to how they can use it. It is these unexpected discoveries that flow from powerful new facilities that have traditionally been the hallmark of progress in research.

We do know that most of the early advances in laboratory research in the Space Station will be in areas where there is a strong ground-based component of the activity.

An excellent example involves the role of space in advancing understanding of molecular structure. A roadblock in past efforts to synthesize large molecules on the Earth has been an incomplete understanding of the basic structure of such molecules. Using space to grow much larger pure crystals than is possible on the Earth, because of the absence of gravity, and then using the increased flux of X-rays possible with new accelerator facilities on the Earth, and supercomputers to unravel the structural data gained from X-ray analysis of the space-generated crystals, researchers will be able to synthesize complex molecules. The potential of this capability for a wide variety of applications, particularly in the area of pharmaceuticals, is truly immense.

The Space Station is an essential ingredient in any potential manned missions to Mars and, to a lesser extent, the Moon. The essential nature stems from the need to "flight qualify" man for extended stays in space. Special attention needs to be placed on assuring that a crew can not only survive a trip to Mars, but will be able to function effectively and quickly once there.

I have discussed here only very representative examples of the types of activities that are either significantly enhanced or fundamentally enabled by the planned Space Station. Many more examples can be cited.

Let me next turn to the revised baseline configuration or phased approach for the Space Station program. The revised plan includes two polar platforms, with one provided by our international partners; two attached payload locations; and the pressurized volumes. A co-orbiting platform, servicing/assembly facility, three additional attached payload locations, and increased power are deferred until the enhanced configuration. Although there are no immediate gains to the user community from the phased approach, it provides opportunties for U.S. researchers to recover a leadership role in microgravity sciences.

Let me conclude with some comments about preparation for the Space Station era. There is no question that the delays in launching the Space Station will have an adverse effect on many areas of Station-oriented science. However, in those areas that stand to gain the most from the Station, that is microgravity research, there are options which I believe can help fill the gap for research experiences in the early to mid 1990s. Potential opportunities could involve an Extended Duration Orbiter to enhance the on-orbit time per Spacelab flight, more priority for additional Spacelab flights on the manifest in the early 1990's and government sponsored use of facilities such as the privately developed Industrial Space Facility. I believe that if this array of opportunities is adequately exercised we will be in a position to use effectively the Space Station when it becomes operational in the mid 1990s.

This concludes my written statement, Mr. Chairman. I would be happy at this time to answer any questions that you and other members might have.

Senator RIEGLE. Thank you.

I think you just touched on it in passing, but the fact that we will have this, we will have people out there for extended periods of time, you know, automatically allows us to begin to learn what we need to do about people being in space for extended flights on out into the future.

So we get all those benefits as well.

Dr. Banks.

Dr. BANKS. I would like to take advantage of your offer to put my written material into the record.

To give you a little background, since I have not appeared before you before, for three years I have been Chairman of the NASA Advisory Committee on Scientific Uses of Space Station. On the other hand, I am also an academic space scientist, with various experiments and so forth. And I serve on NASA's Space and Earth Sciences Advisory Committee.

So I have a somewhat unique perspective of the space station. During this week, at this hearing and others, I want to make it absolutely clear that there is a very strong scientific need for what we call man-assisted space research and its use on a space station.

You will hear complaints from the science community about space station for a variety of reasons. It is easy to criticize a facility such as that, and especially one that is ten years down the line from today.

But in fact, as a result of the task force work, we know that all science disciplines can find very first-rate scientific activities to accomplish. So I would like you to be very clear about the message from the scientific community on that.

That does not necessarily mean that the space station is a perfect project, and I would like to talk about various aspects of that. I was going to draw a few paragraphs out of the written material that I will discuss with you in a moment, and also some of the questions that you have given me, because some of them probably will not get asked.

But let me tell you first what it is about a space station that is important to the scientific community. There are five things, and Mr. Myers and David Black have touched on one immediately, which is this question of electrical power.

Electrical power is a very unique resource in space, and with 50 or 75 kilowatts—75 kilowatts makes us number one, and that is very important to the users, even though there would be a considerable amount of energy that is required to support the facility.

Senator RIEGLE. I do not think we want to take ten years and spend certainly what would be more than $14 billion to be number two. I am not sure what the point of that would be.

Dr. BANKS. I will amplify on that in a moment.

Senator **Riegle**. Let me tell you what we are going to do here in order to complete this hearing, because those are the second bells on the floor and I will have to leave in a couple minutes in order to cast this vote. It is a key vote and not just a procedural vote, and I have got to be instructed from the floor.

So what I am going to do is a procedure that we sometimes use in situations like this. I am going to ask Mr. Kress, of the staff, to conclude the hearing in my absence, so we can hear the rest of your testimony and take it on the record.

And I would like you to feel free to go into the detail, because we need to get it and I want to get it. So I do not want you to feel hurried in terms of finishing your remarks. But why do you not start on down through the rest of those five factors and then go on to your other points.

Dr. **Banks**. Fine. Let me run over those quickly, because I feel you know them also:

The capacity for instruments of large mass or volume, absolutely essential;

Human beings to repair things, to put things in operation, and especially the sciences which do not have a history of automation, and I am speaking specifically of the materials processing and life science;

Finally, the opportunity to do them over periods of many weeks and months. You allude to that in terms of the permanent presence. In fact, you do not need a permanent presence. You just need the opportunity to conduct research over extended periods of time.

And finally, something that has been overlooked, I feel, is that there is an opportunity for frequent transportation to space, and that is guaranteed by the need for logistics and replacement within the system itself.

You have mentioned the Soviet system and I have a special message for you there. I have been part of a study group on the Soviet Mir station. I have a fair background in that. The one area where we stand to lose most in this ten year standdown is in the life sciences and the knowledge of human behavior in the weightless condition.

If in fact we are contemplating going to Mars or any other long term venture, planetary exploration, unless we get an equivalent period of time to test humans for six months, eight months, ten months in space, we will not be ready to go to Mars.

That is a bottom line. You cannot test monkeys, you cannot test small biological systems.

Senator **Riegle**. How do we solve that problem?

Dr. **Banks**. You know, probably, of my urging for a more rapid development of the space station, and you have heard various alternatives discussed. The only way is to be in space with human beings that can be tested with centrifuges, that can be tested for their reactions to that particular condition.

You cannot mimic it here on Earth. You cannot mimic it in seven day missions in the space shuttle.

Senator **Riegle**. How might we do it, though, within the plan that has been described here?

Dr. BANKS. The only option I see available is the possibility, as Mr. Myers pointed out, of going to a heavy lift launch vehicle and an early form of the station as it is now planned.

You probably know that there are ways in which, if a vehicle like that was developed, if the modules were developed, you could launch probably in 1993 or 1994.

I think we have worked ourselves into a box. That is about the best we can do, and we should not lose the opportunity to move into that if it becomes possible budgetarily or technically.

Senator RIEGLE. I am going to have to excuse myself. Let me do so in an orderly way so that Mr. Kress might come up here and sit in and take the rest of your testimony.

I appreciate your testimony. I am sorry it was squeezed against these time constraints. But you know, it is somewhat analogous to the problems we have been discussing today. So I appreciate your testimony.

Mr. KRESS. If you would like to continue.

Dr. BANKS. I talked about the effects of weightlessness on humans.

The second area that I feel, and again projecting them into the Soviet capabilities, where we are certainly going to see a ten year standdown in our capabilities has to do with the physical, chemical, and biological properties of materials.

In fact, the Mir itself was not a consequence of a one-time project, such as we are contemplating, but was an outgrowth of the strong commitment to manned space flight generally. And if you look at their progress through Salyut's 1, 2, 3, up through Salyut 7 and the Mir as it now stands and whatever comes beyond, you will see that they have done enormous amount of work in studying materials science under weightless conditions.

And I think as a scientist, not particularly in that area, but as an onlooker to progress in that area, it is a tremendous deficit for our system that we have to stand by and wait until 1996 to see our capability grow.

I should say that I have no reservations about the quality of the planned station that we are talking about here. I personally, David Black, and members of the task force have worked for three years very hard and very closely with NASA to make sure that what you see here will include in its interior very valuable scientific resources.

The problem is the timing, and I feel that in discussions and the prefatory comments by the committee, it perhaps did not realize the tremendous impact the Challenger has had on science plans.

A ten year hiatus in science activities, 1986 through 1996, that is a long time in a fast-paced world of technology. And somehow we have to live through that. And one way, of course, is to move forward more rapidly with space station, and I would urge that if there are budgetary means to do this that we try to hold to the original 1994 period.

There are also other activities which relate to existing and near-term manned space activities which would help.

Well, let me also say something about the multi-stage plan. I do not have much detailed interior information about this, because it is simply a new activity. I have discussed it with NASA.

I share the feelings of the committee that in fact it does expose a certain aspect of space science to considerable uncertainty. I am referring in particular to the people who are dependent upon detached payloads. Remember that the space station itself is a carefully balanced activity in terms of endeavor.

The pressurized modules take care of materials science and microgravity sciences, life science. Attached payloads help with problems related to general astronomy, Earth observations, and so forth. And we have free-flying platforms which will tremendously aid Earth observations.

The two-stage approach hits right at the heart of that and introduces uncertainty into that plan by deferring to a later fiscal year, a later period, important decisions about the progress of attached payloads.

And I hear that message coming back from astronomy, from planetary observations, planetary telescope, solar observation, solar terrestrial. And the question is, where are we, from those communities, if in fact we are going to go directly to something that emphasizes so strongly the microgravity approach.

So from the point of view of the science community, the most unfortunate aspect of the two-stage program, which may be dictated financially and I certainly do not dispute that, is the fact that the first stage is still very late as measured on this time scale that has been imposed upon us by the Challenger accident.

That is what has changed. That is why many of NASA's plans have gone awry. The STS simply cannot handle the payload elements and the modules that they once planned. I think they have done a wonderful job of recouping from such a dramatic change in space transportation.

Let me turn now to what we can do to ameliorate the situation with respect to space research. There are certain things that can help. My committee has requested NASA to consider these carefully, and I would urge that you personally take an interest in these also.

I talked about accelerating the pace of development of the space station. That is a budgetary issue. We all know that the limitation being put on the space station program office now comes from OMB and an attempt to rationalize many aspects of the national budget.

On the other hand, it is seldom that you have such dramatic accidents and such a dramatic fall-out in terms of the aspirations of an important part of the American science community.

Therefore, the opportunity to accelerate this, according to comments made by the Associate Administrator, I believe last week, perhaps in sessions here in Congress, should be taken very seriously. There are ways to speed up the space station, to bring it more rapidly to bear than what was shown on the slide earlier.

Let us talk about other things. For two years, the space station task force has talked about a low cost extended duration orbiter. That can more than double the science yield of a given shuttle flight. Seven days versus 14 days makes a big difference.

Proposals to do this are relatively low cost. We have seen prices between $25 million and $100 million. Who knows where the real answer is, but it is something that can help now, so that when the shuttle resumes flights we increase the productivity of what small number of flights that we have.

Secondly, the task force has had briefings from space industries about the industrial space facility, a man-tended module which would have capacity to help fundamental microgravity materials research.

We urge NASA to proceed with discussions. Perhaps they are far advanced at this point. We do not know. But some means has to be found to at least get started in these microgravity areas.

However, you have to realize it does not help the life sciences prove the effects or investigate the effects of weightlessness on humans. We are going to lose that unless we have a space station earlier than we see it now.

It is also possible to think about giving a higher priority to space labs in shuttles. As you know, it has been pointed out that the space lab program for the United States once the shuttles begin flying again will be limited to only three.

What was once the flagship of space science has been reduced down to a very almost trivial number of opportunities before the space station. Bringing aboard space labs is hard, but it is something that can be done, increasing that priority.

Finally, I want to talk about the possibility of rescheduling one or more of the large platforms that are already in the space station program. There is a need on the part of the scientific constituency for platforms, and it is conceivable to do several things:

One, the polar platform could be moved forward by several years. There is a cost consequence. We are all aware of it. But in fact, there is nothing to prevent that from becoming an important part of the NASA program earlier.

Secondly, it is also possible that one of the large platforms destined for orbital use could be made available as a multi-user facility, to help ease the dramatic fallout of attached payloads that have disappeared from the NASA program in the period 1992-1995, to give them a chance to fly and extract the science which they are capable of doing.

Finally, again my mind returns to things having to do with Mir because it is such a symbol of the progress. The American science community has nothing to be ashamed of in the quality of the science that it undertakes. Tremendous progress—our plans have been thrown awry by the problems with the STS system, the Challenger accident.

But there is still a message to be learned in Mir, the Cosmos modules, the Progress supply ships, the Salyuts, and the Protons. Each of them has its own part in the Soviet space program.

Left to themselves, the Soviets, I am fairly sure, would not have a competitive program in terms of results coming out in the science domain. We maintain a diversity of interests, a wealth of technical capability, instruments, and a variety of techniques to make sure that when we go to space we are superior.

However, the problem that you will see appearing, and appearing already with Mir and the Quantum module that is now there, is the fact that they are actively soliciting very technically adept scientists from other countries to participate in their program.

Three of the four experiments in the Cosmos module on Mir now are from Western Europe, and in terms of competition they are fully the peers of the U.S. science community. Over the next decade, we can count on remote sensing, life science, and materials science being modules on Mir, and in each of those you will see very active Western European and perhaps even Japanese participation.

That is a cause for challenge to our American science efforts, and especially over a ten year standdown when we have very few ways of taking our own experiments into space.

I know you probably have many questions about this and other things, and I would like to request permission to include two other things in the record. The Conclusions from the SESAC Task Force on Scientific Uses of Space Station are the most recent information from the science community about the use of space station. I would request that that be put into the record.

In addition, to show our honesty and straightforwardness in dealing with NASA, I have collected letters for the past six months of our advice given to the Associate Administrator for Space Station and to the Associate Administrator for Space Science and Applications. And I would request that also be made a part of the record.

Mr. KRESS. Without objection, let the record show that both will be submitted and accepted.[1]

Dr. BANKS. That concludes my testimony.

[The statement follows:]

STATEMENT OF DR. PETER M. BANKS, PROFESSOR OF ELECTRICAL ENGINEERING, STANFORD UNIVERSITY, STANFORD, CA

Mr. Chairman and members of the Senate subcommittee, I appreciate the opportunity to discuss with you various aspects of the U.S. Space Station program. My perspectives have been gained over the past three years as Chairman of the NASA Task Force on Scientific Uses of Space Station (The so-called TFSUSS). I am also an active participant in NASA's program of space research using the Space Shuttle and serve on NASA's Space and Earth Science Advisory Committee.

I want to begin with a strong statement about the scientific need for man-assisted space research and its support via a space station. For three years the Task Force has probed the plans and needs of the various scientific disciplines involved in space research. Without exception, we find that all scientific disciplines can find important uses for human services in space and the new facilities. Space Station resources represent a means for greatly improving scientific research in space and enlarges our earlier capabilities based on the use of unmanned satellites and the Space Shuttle.

Let me be specific. Current plans for Space Station include three types of accommodations:

Pressurized volume. This will be used to support adaptive laboratory science work where complex experiments can be conducted in ways similar to what is done in ground laboratories.

Externally placed payload attachment points. These will support an ambitious variety of Earth-looking and outward-looking telescopes and other sensors and experiments. They also enable the establishment of specialized research facilities devoted to specific types of experiments which exploit the space environment.

Free-flying platforms. These are derived from Space Station technologies and can host a variety of remote sensing instruments.

Each of these contributes in an important way to the overall concept of the space station. The balance of resources between them is a unique aspect of the Space Station Program and one which has been jointly developed by NASA and the research users.

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[1] The submissions were not reproducible and are in the Committee files.

The Space Station, as it is now planned, has five important resources. These are: (1) Its substantial electrical power (which is a precious resource in space), (2) Its capacity for instruments or specialized facilities of large mass or volume, (3) The wide variety of essential services which can be provided by humans, (4) The opportunity to proceed with science investigations over periods of many weeks and even months, and (5) The opportunity for frequent transportation to space.

These features, when added together, are not found in any previous flight system. Their synergism opens the way to important, new science activities which could not otherwise be undertaken with Shuttles or other existing space platforms.

Important projects which can be reasonably undertaken only with a space station include:

(a) Long term studies of the effects of weightlessness upon humans and other living organisms. The results from such studies must be known before this nation can contemplate any manned exploration of the inner solar system. Centrifuges and access to variable gravity conditions are essential to this work.

(b) Studies of the physical, chemical, and biological properties of materials formed and altered in low gravity conditions. The most important progress to date in microgravity materials science has been done in Europe and by the Soviet Union. High power furnaces operated for weeks and even months in a low-g environment are essential to progress in understanding the various physical processes involved.

(c) Industrial materials technology operations which exploit the discoveries of materials science to produce important items having strategic and even commercial value.

(d) Interactive observations of the sun and earth using new instruments of great complexity and capability.

(e) Active experiments in apace with various gases, charged particles and magnetic fields,

(f) Large detector experiments for astronomy and planetary observations,

(g) A variety of small experiments which can be easily taken to a space station and operated for periods of months via remote control, giving support to research programs involving astronomy, solar-terrestrial physics, earth observations, life science, materials science and technology, and fundamental physics and chemistry in space.

I would now like to turn to specific questions sent to me in your letter of invitation.

You have asked about the concerns of the science community about the proposed two-phase approach to the development of Space Station. Unfortunately, this proposal has not been discussed before the TFSUSS and the only specific information available to the science community has come through the media. This is regrettable since we can only speculate about the various trades made to achieve this plan.

In view of what I have said about the need for balance between capabilities, the two stage plan has a clear implication that attached payloads will be treated in the later, second stage. This means delay and difficulties for those activities. As you recall, the dual keel approach was specifically designed to accommodate these users.

I also understand from colleagues in the life sciences that they are very concerned about the prospects for centrifuges. If they are to understand the effects of weightlessness upon humans and animals, a large centrifuge is essential. By placing a large centrifuge in the second stage planning, there may be an implication of delay for gaining answers to questions relating to long term adaptation to weightlessness. This might have a serious consequence upon our ability to plan for a manned mission to Mars.

From a political perspective, the staging plan holds dangers to the attached payload capability. Will, for example, a future administration be able to justify the additional stage 2 expense in the face of alternatives such as free-flying platforms or the desire to initiate a new, manned interplanetary venture? In view of the plans for the co-orbiting platform late in the 1990's, it is entirely possible that planning for that free-flying facility could be in conflict with the desire to implement the dual keel structure.

From the point of view of the scientific community, the most unfortunate aspect of the two stage program is the fact that the first stage still is very late, as measured on the scale of needs of the users. Unless special action is taken, the Space Station will come a decade after the Challenger accident. In the fast paced world of science and technology, that is a lifetime of waiting, and much of the momentum of research dependent upon manned space flight will have dissipated.

With respect to power, there is no question that the estimates of 75 kW are realistic in terms of the needs of the Stage 1 users. The TFSUSS is on record as strongly supporting this power level, and every effort must be made to assure that this capability is present in Stage 1.

Turning now to the platforms, there is strong support for the concepts of polar and co-orbiting platforms. What appears to be lacking is sufficient funds to begin the designs and prototypes instruments which will be placed aboard these facilities. This is especially critical for the polar platform where state of the art remote sensing instruments are involved. In view of the consequences of the Challenger accident, one can question whether it might not be worth considering advancing the schedule for these facilities? In this case, budgets for the science would have to receive immediate attention and close collaboration with ESA would be involved.

Finally, I turn to the question of what can be done to ameliorate the situation facing space research as a consequence of the Challenger accident. If, indeed, the Space Station is to be held to its current schedule, the science community participating in manned space activities is in very serious difficulty. Owing to the decreased availability of the Shuttle, we can count on a drastic reduction in Shuttle science payloads, including Spacelabs. Indeed, we now have NASA flight manifests which show an alarming dropout of previously planned missions. These lost flights strike at the heart of our ability to maintain a satisfactory program of space research. All disciplines and many research institutions across the country are involved in this unfortunate situation.

There are certain things that can be done to help. My closing comments focus on the question of alternatives. They are made in the hope that NASA and Congress will work together to find a way of incorporating new elements into its manned space program in support of space research.

One positive step would be to accelerate the pace of development of the Space Station itself. Previous testimony by the Associate Administrator for Space Station, for example, indicates that the principal difficulty with holding to the original plan for a substantial early science capability in 1994 is a peak funding limitation set by OMB. There is great benefit to this country in keeping this original schedule and I would urge that the increase in funds involved be regarded as an important step towards reaping the rewards of new knowledge made possible with the Space Station. Additionally, one could think of the possibility of a space station of lesser initial capability appearing in the early 1990's which might grow according to user needs over the following five years. However, it is my impression that NASA doesn't want to seriously consider this possibility.

Other alternatives also exist if the Space Station must hold to its current schedule and configuration. According to the NASA Deputy Administrator, the use of a Heavy Lift Launch Vehicle would permit a rapid deployment of initial capability and greatly reduce the number of Shuttle flights required to reach a particular state of operation.

Other important, and perhaps more practical, things can be done to improve our ability to use alternate facilities before Space Station is available. First, a low-cost Extended Duration Orbiter can more than double the science yield of a Shuttle flight. The proposal to go ahead with this innovation has been in front of NASA for more than a year and the TFSUSS strongly supports its development.

Second, the use of the Industrial Space Facility now being offered by Space Industries (or its equivalent) may provide an interim man-tended capability to help with fundamental microgravity and other studies prior to using Space Station. This opportunity, also strongly supported by TFSUSS, should be strongly encouraged. If this course is to be adopted, funding for the necessary instruments must be started soon.

Third, it is also possible to reschedule one or more of the large platforms included in the Space Station Program. This could either accelerate present science plans or serve as a stop-gap, new capability to serve as a multi-experiment platform to ease the current experiment manifest.

Finally, increased priority for science use of the Shuttle could improve the number of Spacelabs and Shuttle flights available to the science community. This alternative comes with a need for increased funding for Shuttle science missions, but in the long run this investment can be viewed as the opening wedge of funding needed to support the later Space Station science operations.

Mr. Chairman, portions of my presentation have been based upon a recent fact-finding meeting of the Task Force on Scientific Uses of Space Station. In order to make this detailed information available to this committee and others, I would request your permission to include the TFSUSS written report in the record of this hearing. Furthermore, for the benefit of this committee, I would also request permission to enter into the record copies of TFSUSS advice provided to NASA over the past six months. This correspondence provides an important background to the current discussions.

This concludes my testimony. Thank you again for the opportunity to appear today. I will be pleased to answer any questions you may have.

Mr. KRESS. In order to complete this hearing and the record without a series of written questions, perhaps if Dr. Black would like to comment on Dr. Banks' remarks, since he had a much more extended period of time.

And in particular, if you could comment on his recommendations of interim steps, be that acceleration of platforms, an EDO, an industrial space facility, or enhanced space lab missions.

And then in conclusion, if you could both just quickly give the committee your impressions on the instrumentation that is required for the space station program, and if Dr. Banks could comment on the task force findings. We will close the record at that point.

Dr. BLACK. Well, I would concur basically with what Dr. Banks said in terms of the science use and needs in terms of the space station.

With regard to the interim or the bridging activity that is clearly needed as we head toward the space station activity, the task force, as he said, has long endorsed the use of the extended duration orbiter as a way to assist in getting flight experience for the microgravity sciences.

I think it is important to recognize that those particular disciplines are in a relative sense quite immature when you compare them with the classic space sciences, the observational sciences. So in fact they can benefit tremendously from additional flight time on orbit. And the EDO is certainly one way, and it would appear to be a fairly low cost and effective way, to begin giving them that kind of bridging experience.

The space lab flights are particularly helpful if we, as it appears, will be a little later in arriving with the space station. In that interim time, I think we would all like to see increased emphasis and priority given to space lab opportunities as we go into that time.

Clearly, the ISF is an enabling kind of capability for the very long duration flights in the early stages as we build toward space station. As Peter said, it does not help much with the life sciences because it is not permanently manned.

One nice aspect of the ISF is that the design is proceeding in a way that recognizes, in fact depends in many critical ways, on the existence of the space station later. Therefore, those who design their experiments, their racks, to go into the ISF in effect have already designed them for the space station, so that it will be an easy transition from that particular point of view as they move on into the space station.

So I think that those interim capabilities, those bridging experiments, if you will, that could be flown on that range of opportunities, will be very useful and in some cases very important to make full and effective use of the space station in terms of the laboratory research that would come along.

As far as the instruments program, development of instruments for use of the space station, that has long been a concern of the task force and it has long been a concern of mind from my position as chief scientist on the space station.

I think the Office of Space Science and Applications is beginning to come strongly to grips with this issue, and I expect that the committee will see in the coming years a very vigorous, well thought out plan as to how it, the Office of Space Science and Applications, will use the space station.

I think it is important to bear in mind that, if you look at past history, the science community was exercised in a way to use the space lab well before it came along. And those of you who remember, there was a great frustration because the space station lab, the shuttle program, was significantly delayed.

Many of the announcements of opportunity, people were selected—for all I know, some of the PI's have long since died and have not had their flight opportunities. That is an experience we do not want to see repeated here. So I think it is prudent on the part of the Office of Space Science and Applications and the science community to pace themselves in some sense with the development of the major facility, and that is what I think is going on now.

So I think we will see, with Dr. Fisk now as head of the OSSA program, a very strong effort to define, plan for, and budget for, and ask for increased budget in fact, in those areas of the microgravity sciences which have been traditionally in some sense underfunded, as you look at the space station and the capabilities it will provide.

Mr. KRESS. Dr. Banks, would you like to comment on that?

Dr. BANKS. Yes. I agree with the things that Dr. Black is saying to a large part. In fact, as you know, he serves as a member on our task force. So if he does not agree, then we beat him into submission.

But in fact there is a—you have given me an opening to say something that is important, and that has to do with the anticipation of space station and the fact that the plans as they have gone forward now have included no funding in the plans for science activity.

If I was to pinpoint one worry in the general space research community, it would be that, with a $14 billion facility, there has not been an allocation of one cent towards the science activities in terms of advanced planning.

I am not talking about commitments, such as Dave was mentioning with respect to selecting PI's, but in terms of year by year wedges that are open, that show you the breakout of funding as it will go into the microgravity sciences and advanced planning, definition of those instruments and facilities and so forth.

And I have a deep worry that when we come to that phase of outfitting space station for the actual users that we are going to be between a rock and a hard place. It is going to be expensive.

If I was building a university laboratory, I would say between 30 and 40 percent of the initial capital cost of that laboratory would actually be spent in instrumentation. Now, if that is the case and we are talking about $10, $12, $15 billion space stations, we have to begin planning now, I think, in the budgets, warning you in Congress, warning the science community, that new funds are needed to take care of space station.

You simply cannot divert funds from the existing, already strained programs to space research and expect suddenly all space research to be done on the space station. Space station is by and large an add-on to science capability. It is not something that now sucks up previous activities from the great observatories or from Earth observations.

It is new money, new undertaking. And in reading the journals and media, I do not see that realization coming forward that in fact you are committing to a much larger activity than simply the building of a facility.

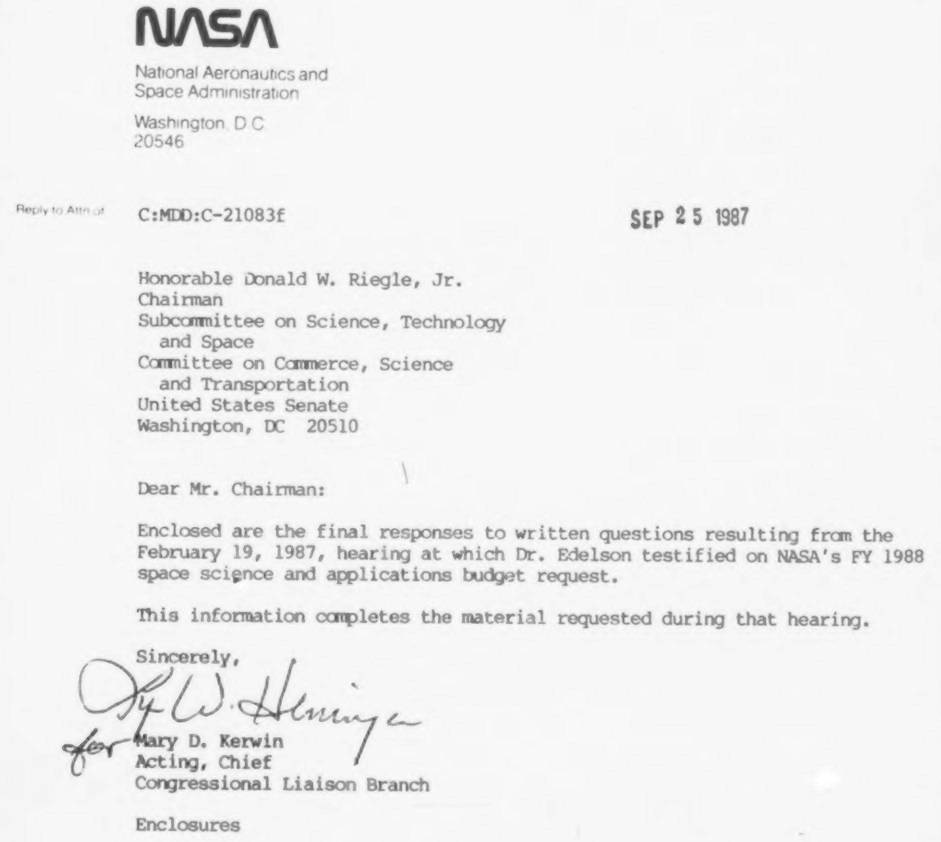
Now, the use of that facility is important, but it can only be done with new funding, and it is expensive.

Mr. KRESS. I would like to thank you both for coming and for your testimony.

The subcommittee will now stand adjourned. Thank you very much.

[Whereupon, at 4:28 p.m., the subcommittee was adjourned.]

[The following information was subsequently received for the record:]



NASA
National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of: C:MDD:C-21083f

SEP 25 1987

Honorable Donald W. Riegle, Jr.
Chairman
Subcommittee on Science, Technology
and Space
Committee on Commerce, Science
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

Enclosed are the final responses to written questions resulting from the February 19, 1987, hearing at which Dr. Edelson testified on NASA's FY 1988 space science and applications budget request.

This information completes the material requested during that hearing.

Sincerely,

for Mary D. Kerwin
Acting, Chief
Congressional Liaison Branch

Enclosures

Responses to Written questions submitted by Chairman Riegle.

Question 1: In your statement, you discuss the proposed Space Station program and its meaning to the space science community in several different places. What is interesting about your Space Station testimony is the fact that each and every candidate space science payload is qualified by the term "if approved."

a. Would you please inform the Subcommittee as to what space science and applications missions have been approved for incorporation into the Space Station program?

b. What are the leading candidates for the core station, the co-orbiting platform, and the polar platform?

Answer 1a: At this time, there are no new science missions approved for incorporation into the Space Station program. However, a number of experiments which are candidate payloads for the Station are in definition phase, and are being funded as part of the OSSA Advanced Development for its Space Station Initiative which is a candidate new start for FY 1989. Our planning for utilization of the Space Station includes a mission approach which builds to use of the station through precursor Shuttle and Spacelab flights. There are a number of flight-qualified experiments which we believe are suitable for early "pathfinder" use on the Space Station. We propose over the next year to develop, through our scientific advisory committees, a strategy for selecting payloads which will maximize the science return from the initial Space Station operations. We believe this should be done in a competitive fashion, including appropriate peer review, in order to insure the most effective utilization of the Space Station. NASA expects to issue an Announcement of Opportunity for the Earth Observing System (EOS) in January, 1988, with a new start planned for 1991 and launch in 1995. The Space Station Polar Orbiting Platform is a major component of the EOS. The platform will carry multidisciplinary complement of earth science instruments to observe the solid earth, oceans and atmosphere. Other missions, instruments and experiments will be submitted for new start approval on a schedule commensurate with their planned deployment on the station.

b. Candidates for the platforms are addressed in the response to the first part of this question. The following list of missions and equipment are candidates under study for the core Space Station beginning with the first payloads in the early assembly phase, continuing through station completion.

A representative list of early attached payload candidates that are under study for deployment prior to upper and lower boom availability, includes:

a) Plasma Interaction Monitoring System for plasma research and for understanding the potential instrument contamination effects of station/plasma interactions
b) Cosmic Dust Collector for Exobiology and Solar System Exploration research
c) Earth Radiation Budget Instrument
d) Large Area Modular Array of Reflectors to study X-Ray

Astrophysics

e) Solar Terrestrial Observatory/Solar Instrument Group

A representative list of payloads which could be deployed on the station as its resources and operational modes mature includes:

f) Astromag
g) Astrometric Telescope Facility
h) Solar Terrestrial Observatory/Plasma Instrument Group
i) Tropical Rainfall Measurement Mission
j) Laser Atmospheric Wind Sounder
k) Pinhole Occulter Facility
l) Tropical Regions Imaging Spectrometer

Microgravity Research will be the principal activity in the pressurized laboratory modules, and will include both materials science and life science experiments. Facilities and instrumentation will be built and flown on Spacelab for transition to Space Station by the time the U.S. Lab is ready in 1995. This approach will support materials research in fluid dynamics and mass transport, glasses and ceramics, electronics materials, combustion science, metals and alloys, and biotechnology.

The Materials Science Research facilities planned for deployment on the station include:

a) Modular Multizone Furnace Facility for research in solidification and crystal growth
b) Modular Combustion Facility for testing of fundamental theories of combustion
c) Fluid Physics/Dynamics Facility research in room temperature and cryogenic fluid behavior
d) Modular Containerless Processing Facility for research in glasses and metals, allowing melting and solidification studies without crucibles
e) Advanced Protein Crystal Growth Facility for growth of protein crystals by several different methods
f) Biotechnology Facility for research in processing of biological materials

Definition studies and advanced technology development activities have begun for these facilities, and nine Shuttle-based flight opportunities are currently anticipated.

The Life Science research will also be based on a steadily paced program building through Shuttle and Spacelab missions which will deliver a set of facilities to the Space Station to support research in Space Medicine, developing foundations for human health and productivity in space; Gravitational Biology, understanding the basic influence of gravity on living systems; Closed Ecological Life Support Systems, developing the fundamental technology to support long term space flight; Biospherics, studying global scale life processes; and, Exobiology, studying the phenomenon of life-generative compounds and processes in space. An important aspect of this research will be the understanding of human health and performance in space necessary to allow extended duration crew time on Space Station, thus reducing requirements for Shuttle visits.

The Life Science facilities planned for deployment on the Space Station include:

a) 1.8 Meter Centrifuge Facility to provide an on-board 1-G control environment to allow separation of the influence of weightlessness from other effects of space flight; to allow testing the responses of living organisms to gravitational forces at various stages of adaptation to weightlessness; and, to provide fractional G forces needed to study force-response functions and threshold effects.

b) Life Science Research Facility to provide the basic biomedical and biological research equipment, plant and animal growth facilities, and various supporting facilities definition studies and advanced technology development activities have begun for these facilities, and several Shuttle flight opportunities are identified.

Question 2: Currently, there is a draft U.S.-U.S.S.R. agreement being circulated for agency comments. I am informed that several of the items contained within this agreement concern NASA's space science programs.

a. Would you please comment on this proposed agreement and how your office is involved?

b. What type of joint activities are being contemplated?

c. Do you intend to consult with the Congress about this proposed agenda?

d. Are there currently any discussions underway concerning a possible joint U.S.-Soviet Union Mars sample return mission?

Answer 2a: The Office of Space Science and Applications was responsible for the initial U.S. cooperative proposals that were eventually incorporated in the annex to the draft U.S.-U.S.S.R space agreement, together with certain Soviet proposals. Mr. Samuel Keller, the Deputy Associate Administrator, was a member of the U.S. space experts delegation which traveled to Moscow in September 1986 for technical discussions of these proposals. He also participated in the U.S.-U.S.S.R. negotiations on the Space Agreement held in Washington, DC in late October 1986.

Once the agreement is signed and enters into force, OSSA will be the NASA program office responsible for the five joint working groups called for in the draft agreement and for leading the implementation effort of the agreed cooperative activities.

b. Once the agreement has been signed, we expect joint working groups to be established in five discipline areas: solar system exploration, space astronomy and astrophysics, earth sciences, solar-terrestrial physics, and space biology and medicine. An initial list of cooperative projects in all of these areas has already been agreed upon at the negotiating team level. The projects typically involve exchanges of scientific data and coordination between existing missions -- no joint missions are proposed.

c. A space biology and medicine agreement is being circulated for comment. We will gladly brief you or your staff on the general provisions of the agreement at your convenience.

d. Such a mission has been discussed unofficially among scientists over the past several years. In official bilateral channels, there has been no consideration of a possible joint Mars sample return mission.

Question 3a: Could you please comment on the recent conclusions of the Dunbar Report that focused on NASA's materials processing program--the report said the program needs more funding, more flight opportunities, and better organization and that potentially vigorous commercial programs are evolving in both Japan and Europe--but not the U.S.?

b. Is NASA considering the consolidation of all materials processing activities in the Office of Space Science and Applications--a step this Subcommittee would support?

c. What steps are being taken to ensure flight opportunities for materials processing payloads--including those of the Space Science Office, the Centers of Excellence, and the Centers for Commercial Development of Space?

d. Is it true that only one dedicated Materials Processing Lab is currently on the shuttle manifest? How many were planned prior to 51-L?

Answer 3a: Consistent with a series of Decision Memoranda issued in June of this year, the Agency intends to put additional emphasis on the NASA microgravity program. We are reviewing the manifest for additional flight opportunities, as well as assuring that the flight hardware reliability is increased. The budget for the program has grown significantly over the past five years, and we anticipate continued growth.

With regard to foreign programs, several European countries and Japan have begun vigorous programs in materials processing. Commercial involvement to date in those countries has been tentative; however, the respective governments do provide subsidies to enable industry to conduct research.

b. Agency Decision Memorandum No. 16 provided for consolidation of NASA microgravity activities in the Office of Space Science and Applications. We are in the process of working the final details of this consolidation, and plan to brief the Subcommittee when the decision is implemented.

c. The Agency is currently reviewing the STS manifest and a formal manifest is expected soon. A requirement has been submitted for a series of Spacelab missions for materials processing payloads.

d. The final secondary payload manifest, which will contain the Materials Science Labs (MSL), has not yet been established. We expect it to be published in late fall of this year.

The November 1985 manifest listed 17 future MSL missions, not including MSL-2 which was subsequently launched on January 12, 1986.

Question 4: Is it true that there is some confusion over the recently proclaimed White House shuttle launch policy as regards to the launch of commercial materials processing payloads?

Will these issues be clarified in the Force Report that deals with materials processing, joint endeavor agreements, secondary payloads, etc.? What is the status of that Report?

Answer 4: Administration policies for the Shuttle are to phase out launch services for those commercial payloads that do not require manned presence or the unique capabilities of the STS. Materials processing payloads generally require manned presence, and thus will not be restricted by this policy. The Commercialization of Space Review Task Force, chaired by Charles Force, Deputy Associate Administrator for Space Operations, has made recommendations intended to eliminate any confusion over the application of the White House policies. These recommendations are being considered by NASA management.

Question 5: Would you please clarify for the Subcommittee the purpose and scope of the Bugg's Strategic Plan for the Materials Processing Office? When will this Report be complete and how does it relate to Dr. Ride's agency-wide strategic plan?

Answer 5: At the direction of the Microgravity Science and Applications Division, the six microgravity Discipline Working Groups are preparing science and applications goals and priorities in their individual disciplines. (Dr. Charles Bugg is Chairman of the Biotechnology Discipline Working Group, and is, therefore, leading the activity for biotechnology). The purpose of these plans is to lay out a "roadmap" for future microgravity research.

The Discipline Working Groups will complete their contribution to this activity in early fall. We will then integrate these six plans into an overall science and applications strategy for the microgravity program and develop the associated hardware and facilities requirements to accomplish that strategy. The plan will be evaluated against Dr. Ride's activities for consistency with the overall Agency plan.

Question 6: Could you please inform the subcommittee of the current status of the discussions concerning the launch dates for Galileo and Ulysses? When will definite decisions be made on these matters and how do they affect the proposed Mars Observer launch?

Answer 6: NASA is currently planning to launch both Galileo and Ulysses from the Shuttle using an Inertial Upper Stage (IUS). Ulysses also requires an additional Payload Assist Module (PAM-S). A decision has been made to launch Galileo in October 1989 and Ulysses in October 1990.

The Mars Observer is baselined to be launched on the Shuttle/TOS in 1992.

Question 7: What is the impact of the cancellation of the Centaur program on these planetary missions?

And why was the Centaur program cancelled -- were there real risks or only perceived risks as regards to the use of a cryogen on a Shuttle that was carrying a nuclear generator?

Answer 7: The cancellation of the Centaur has stretched our capabilities of launching the Galileo, Ulysses and Magellan missions (all of which had been baselined on the Shuttle-Centaur) but solutions have been found: Magellan will launch on the Shuttle with IUS; Ulysses will also use the IUS together with a PAM-S "kick-stage"; and Galileo will launch on the Shuttle/IUS augmented by one Venus and two Earth gravity assists -- this necessitates a major spacecraft redesign and imposes a three year longer trip time to Jupiter.

The Centaur program was cancelled because of safety concerns to the Shuttle and crew. It was not cancelled because of the RTGs on board the Shuttle for the Galileo and Ulysses missions.

Question 8: Has any preliminary analysis been conducted to determine if it is "safer" to launch the Galileo and Ulysses nuclear generators on a Shuttle or on an ELV? In any case, shouldn't both missions be launched on the same type of vehicle to preclude separate launch integration activities?

Answer 8: NASA is in the process of comparing launch vehicle alternatives -- Shuttle/IUS, Titan-IV/Centaur and Titan IV/IUS for Galileo and Shuttle/IUS/PAM-S, Titan IV/Centaur and Titan IV/IUS for Ulysses. NASA's preliminary assessment is that there are adequate margins of safety on all three approaches (the reason why Galileo is baselined on the Shuttle/IUS and Ulysses on the Shuttle/IUS PAM-S).

The spacecraft for the two missions are sufficiently different that each will require independent analytical and physical integration activities, so there really is no significant saving from using the same launch approach. Other programmatic factors such as the presence of a planetary launch window, availability of a position on the Shuttle manifest, etc., are probably more important. There may be some savings in the nuclear launch safety analysis if both missions use the same launch approach.

Question 9: What are the additional program costs that NASA will incur if the Mars Observer Mission is slipped from 1990 to 1992?

How do these cost compare with the acquisition of a Titan III or Titan IV?

Answer 9: Based on very recent reviews it is our estimate that the cost to the Mars Observer development program of a slip from 1990 to a 1992 launch would be about $120 million. Also based on recent reviews our present estimate of the cost of a Titan III (hardware, integration and launch services) together with upper stage modification would be about $200 million. While a Titan IV could also satisfy the Mars Observer requirement from a technical standpoint it would be considerably more expensive and, according to recent input from the Air Force, could not meet the August 1990 schedule.

Question 10: The first planetary mission to be launched in over a decade, Magellan (formerly the Venus Radar Mapper) is currently scheduled for launch in April 1989 on the Space Shuttle with an IUS upper stage.

a. If for any reason the Shuttle schedule slips, can Magellan be accommodated in another launch window? When? On what vehicle?

b. Is the procurement of hardware for Magellan proceeding on schedule -- in particular, the hardware that is no longer available as a spare from the Galileo program?

Answer 10a: If the Shuttle should slip, Magellan could be launched in November 1989, December 1990, or May 1991 on either the Shuttle/IUS or on a Titan IV/IUS. The flight time to Venus for the November 1989 and May 1991 launch opportunities is six months, while the April 1989 and December 1990 opportunities require 18 months.

b. Magellan development is proceeding on schedule. The Spacecraft Flight System is entering the assembly and test phase at Martin Marietta in Denver. The Radar Sensor development at Hughes Aircraft Company is progressing well and a preliminary test of the radar on the Magellan spacecraft has been successfully undertaken. Procurement of the flight and ground systems, which are no longer available from the Galileo program, is also proceeding on schedule.

Question 11: As a result of the changes in mission profiles that have occurred because of the cancellation of the high energy upper stage program, Centaur, should NASA initiate the development of a new high energy upper stage? When will such an activity be initiated?

Answer 11: The Centaur is a perfectly adequate high energy upper stage for almost all demanding planetary missions. Used on top of a Titan IV expendable, the Centaur G' is the preferred upper stage for the first two Mariner Mark II class missions to the outer solar system, CRAF and Cassini.

Question 12: In order of possible launch, what are the candidate missions for new start status in the Planetary Program and what launch vehicles are being considered? Is a Comet Rendezvous Mission still the highest priority? Wouldn't it make good sense to offload some of the future planetary Shuttle missions and to establish a mixed-fleet capability?

Answer 12: The highest priority new start in the planetary program is still the Comet Rendezvous/Asteroid Flyby (CRAF) mission. Assuming an FY 1989 new start, its projected launch date would be February 1993 on a Titan IV/Centaur G' launch vehicle combination. The Cassini mission to orbit Saturn and probe the nitrogen-rich atmosphere of its moon Titan would be the next new start proposal and would also use a Titan IV/Centaur G'.

In addition to these two missions, other candidates for new planetary starts include a Mars Rover/Sample Return mission launched at the end of 1998 using either a new heavy lift vehicle or two Titan IV/Centaur G' boosters and a Lunar Observer mission somewhere in the mid-1990's that could be launched by either a Shuttle or

Titan III with a variety of upper stages.

Question 13: What is the current status of the space telescope program? When is it scheduled to be launched, on what vehicle, and are there any contingency plans?

What does it cost to store this payload per month? In light of these costs, why did the space telescope receive such low priority on the Shuttle manifest -- the fifth flight? What is the current status of the Space Telescope Institute in Baltimore?

Is it true that the Space Telescope might have power problems-- the solar arrays and the batteries don't provide enough power? What corrective measures are being taken and what is the effect on the telescope's capabilities?

Do you still intend to service the Space Telescope at the Space Station facility once it is deployed--prior to Space Station, the telescope will be serviced by the Shuttle and an orbiting maneuvering vehicle?

Answer 13: The Hubble Space Telescope (HST) spacecraft has completed its integration and functional testing at Sunnyvale, California, following extensive testing in a simulated space environment. While the results were favorable, there were some problems uncovered in the instruments and other subsystems that had to be corrected. Changes to resolve these problems have been carried out this summer at a reduced level of activity, while system-level testing on the integrated spacecraft was suspended. The Challenger accident has resulted in a host of new safety considerations for shuttle-borne payloads, which are being addressed throughout the remainder of this fiscal year. The most extensive of these activities was the recently completed Failure Mode and Effects Analysis/Critical Items List/Hazard Analysis (FMEA/CIL/HA).

Early in FY 1988, when component rework has been completed and the Science Instruments have been reinstalled, the test teams will be reassembled for several months of functional validation testing. This activity will culminate in a "pre-ship functional test" that will ensure that the spacecraft is ready to move to the launch site. At that point, the vehicle will begin a period of minimal maintenance that will preserve its ready-to-ship condition until it resumes the schedule for shipment, launch preparation and launch. Ground system development is substantially complete. However, recent operational simulations have revealed that the ground system is slow in maturing to its design capabilities for throughput and timeliness. Therefore, some further refinement of ground exercises of the ground system will continue until launch. By thus taking advantage of the launch delay, efficiency of the ground system should be increased for post-launch operations.

The HST spacecraft is scheduled for launch by the Shuttle in mid-1989. Preliminary studies have been made of possible alternative launch vehicles, but no plans have been made.

Current expenditures for HST development are about eight million dollars per month. However, these costs are to a large extent offset by not spending money originally budgeted for operations and maintenance and repair. Subtracting these avoided costs leaves a net monthly cost of about three million dollars. However, as noted in the first paragraph, this period cannot be characterized as "storage."

The HST spacecraft is receiving a high priority among scientific payloads for Shuttle launch. The Tracking and Data Relay Satellite vehicles will be launched ahead of HST, because they are a critical component of our overall space operations complex and are essential to the operation of HST and many other space systems. The priority of the DOD payloads to be launched ahead of HST are justified by the DOD, not by NASA.

The Space Telescope Science Institute in Baltimore is fully staffed to the level set by current HST program activity (approximately 250 personnel). Development has been completed on the Science Operations Ground System (SOGS). The Institute operates and maintains the SOGS, and is prepared to carry out the scientific functions of the HST observatory. They are currently participating in prelaunch testing and training, along with other elements of the HST ground system.

As a result of system-level testing of the assembled spacecraft, two requirements have been identified for modifying HST power management. First, thermal/vacuum testing has shown that heater power loads needed to maintain component operating temperatures were somewhat higher than expected. Second, experimental data show that power reserves needed to implement the spacecraft's "safemode" protection in an emergency are thinner than expected.

Our response to the thermal balance problem will be operational strategies to reduce power demand, while minimizing impact on mission performance. Our response to the safemode implementation situation will likely be twofold: first, to modify some hardware and software to shorten the safemode execution time, and second, to modify commanding procedures to improve recovery from safemode condition. We do not expect that these measures will have any effect upon the Space Telescope's capabilities.

Looking to the future, we are pursuing two initiatives to increase power system performance and reliability. Our baseline plan has always included development of a second generation solar array by the European Space Agency. These arrays, to be installed either before launch or during a Shuttle maintenance mission, will substantially increase HST power margins. In a new initiative, we are developing a new generation of nickel-hydrogen batteries as alternatives to the present nickel-cadmium batteries. The new batteries have the potential for longer lifetimes and greater energy reserves. After further study and development, a decision will be made about using the nickel-hydrogen batteries at launch or during a later maintenance mission.

The potential for using the Space Station as a maintenance facility for the HST is under active study. This possibility appears to be very promising. However, the necessary conjunction of the Space Station and HST orbits will occur only at fixed intervals of about two years. This restricts Space Station servicing to a fixed schedule.

The baseline maintenance concept for the HST spacecraft involves replacement of components by Shuttle-based astronauts during extra-vehicular activity. We are planning for both scheduled and contingency maintenance missions. The role of the Orbital Maneuvering Vehicle is still in the planning stage. It could be used with the Shuttle to provide additional energy for reboost of HST, or with the Space Station to recover and launch HST.

Question 14: What is the current status of the Gamma Ray Observatory Program--is it on schedule for its January 1990 Shuttle launch? Is NASA having trouble with any of the hardware?

Answer 14: The Gamma Ray Observatory (GRO) is on schedule for a January 1990, Shuttle launch readiness date. At TRW, manufacturing of the electronics for the GRO attitude control subsystem and the electrical power distribution subsystem is a peak activity. The propulsion subsystem has been qualified and the hardware is in acceptance testing; the hardware for all of the subcontract subsystems, except the reaction wheels, has been completed, and assembly of the GRO primary platform structure has been completed with verification testing scheduled to start in November 1987. The Goddard Space Flight Center GRO Project is completing development of all major government furnished equipment subsystems for the spacecraft; this equipment will be placed in storage until the beginning of observatory integration and testing in May 1988. Three of the four GRO science instruments have been assembled and manufacturing of the fourth is nearing completion. Calibration with high energy gamma rays and protons has been completed for the Energetic Gamma-Ray Experiment Telescope (EGRET) and the instrument is undergoing functional and environmental testing. Calibration of the Oriented Scintillation Spectrometer Experiment flight instrument was completed in August 1987. Manufacturing of the Burst and Transient Source Experiment (BATSE) is nearing completion, testing of the first detector is in progress. The Imaging Compton Telescope (COMPTEL) has been reassembled and calibration is scheduled to be completed by the end of September 1987. All instruments are to be shipped to TRW for observatory integration in October 1988.

Nearly all of the GRO hardware is experiencing normal hardware development problems of one type or another; with most problems relatively minor and no known "show stoppers." The most serious problems are with two of the science instruments. Testing of the COMPTEL instrument revealed severe electromagnetic compatibility (EMC) problems which required a major redesign of the "veto" subsystem and modification of the flight electronics. Rework of the electronics is in progress, with completion due in April 1988. High voltage power supplies for the EGRET instrument were determined to be non-flight worthy, thus requiring some redesign and complete rebuild. The power supplies are now being rebuilt and integration into the instrument will be completed in December 1987. The major spacecraft hardware concern at this time is associated with the verification of the primary structure. Delays in manufacturing have been caused by complexity due to size and precision of fabrication of the structural parts. In addition, delays have been caused by concerns with the fracturing of a small number of the fasteners used to assemble the structure and the need for additional testing and analysis to resolve the problem. However, we feel these problems are behind us and no impact on the start of observatory assembly and test in May 1988 is anticipated.

Question 15: In light of the excessive demands that already exist with regard to the Space Shuttle schedule, would the High Resolution Solar Observatory (HRSO) obtain a launch slot if approved by Congress? Should new starts be added to a platter that is already overloaded? Could this mission be a Space Station candidate? Why did OMB reject this mission as a new start in the FY 1988 budget submission?

Answer 15: As part of the 1986 effort that redefined the Solar Optical Telescope (SOT) to the HRSO program, a decision was made to make HRSO the top priority Space Station payload for the Office of Space Science and Applications, with the option of it flying as a Shuttle payload if a launch slot became available, or if there are changes in the Space Station schedule. However, early in the summer of 1987, two additional factors emerged which have caused a revision in this plan. First is the fact that the Shuttle manifest shows few if any opportunities for a week-long, dedicated Spacelab flight of HRSO prior to the time when construction of the Space Station itself begins. Second was the growing realization that early Space Station will not in all likelihood be able to accommodate a payload requiring sophisticated pointing, command, and telemetry services such as HRSO will demand. As a result, a decision has been made to restudy HRSO, at modest cost, as a free-flyer, with the potential option of reproposing it as a new start in the FY 1990 or later budget submission.

Although it appears that the platter is full and there are a number of missions awaiting launch, it is hoped that alternate means will be found to launch both NASA and DOD missions through the current mixed-fleet studies.

HRSO did not make it in the FY 1988 submission to Congress because it did not fit within the runout budget wedge along with a new start for GGS.

Question 16: AXAF -- Speaking of new starts, the Advanced X-ray Astrophysics Facility (AXAF) also was rejected as a FY 1988 new start by OMB.

a. Why was this project rejected? And what is its current status? Does NASA still intend to down select -- pick a contractor for this mission -- in FY 1988?

b. Is this still the lead candidate for a Space Station science facility? If so, shouldn't it be a higher priority within NASA's overall budget?

c. Have you considered the deployment of this facility as a free-flyer rather than an attached Space Station payload? Does this improve the science? reduce the cost?

D. In the last year, the overall cost of the AXAF project has been significantly reduced. Has this cost reduction affected the scientific value of the mission or resulted in a reduction of the number of scientific instruments to be flown?

e. If approved, can this mission be accommodated on the Space Shuttle?

Answer 16a: The NASA budget request to OMB for FY 1988 included funding for an AXAF Pathfinder Program. This program, although not a full-up new start for AXAF in FY 1988, would have enabled the Program to reduce implementation risk by making significant progress on critical path and long-lead items. The Pathfinder Program included brassboard development of the science instruments as well as installing a complete tooling and metrology line to enable the fabrication of a single pair of engineering model AXAF optics. Prime contractor systems engineering and design activities were also included. Due to severe budgetary constraints, this program was not included in the final FY 1988 budget request.

The current status of the AXAF Program is as follows: the competitive definition studies of the AXAF observatory were completed in January 1987, following 30 months of in-depth analysis and preliminary design. NASA's plan is to select in FY 1988 a single prime contractor for further activities. The selected contractor will then begin advanced definition and selected studies such as the use of Space Station platform modules, servicing and operations facilities. Also, the interaction with TDRSS, OMV, and with other Great Observatories Programs will be analyzed. In addition, the Program will continue advanced definition and technology development for the science instruments and optics. The acquisition of the raw material for the mirrors, which began in FY 1987, will continue in FY 1988.

b. AXAF remains the lead candidate for a Space Station co-orbiting platform. We plan to have the selected AXAF prime contractor work with the selected Work Package 3 Space Station contractor to define the level to which the co-orbiting platform modules can be used on AXAF. In addition, the AXAF observatory is being designed for primary servicing at the Space Station.

Although the AXAF Pathfinder Program is not in the President's FY 1988 budget request, NASA continues to define the AXAF Program at about the same level as the past few years. This includes funding in FY 1988 to allow for the acquisition of the mirror raw material. AXAF continues to be the top priority Program within the astrophysics community, and this coupled with its potential as a Space Station user, make it a leading candidate for an FY 1989 new start.

c. The baseline program for AXAF is a free-flying astrophysics facility. This observatory satisfies all science objectives for the Program. In utilizing Space Station platform modules as a "co-orbiting platform" as described previously, the AXAF will still be a free-flying facility and not an attached Space Station payload. The decision to use Space Station modules will be based upon comparative cost as well as scientific and technical factors.

d. The overall cost of the AXAF Program has been significantly reduced during the past year. This reduction was achieved primarily through improved and simplified designs in key technology areas, thereby reducing the cost and risk of their development. In addition, the engineering requirements of the observatory were carefully reviewed and scrubbed by the Project and the science working group so as to simplify the observatory design while still satisfying all science objectives.

When the scientific investigations for the AXAF Program were selected in March 1985, it was stated that a peer review of the instruments will be conducted following the definition phase, and that it was likely that three focal plane instruments would be selected for the initial operational period. NASA has not changed its position since that time.

e. The AXAF observatory, along with the other Great Observatories: Hubble Space Telescope, Gamma Ray Observatory, and Space Infrared Telescope Facility are appropriate for Shuttle launches. If approved, it is anticipated that AXAF, which would be launched in the mid-1990's, would be readily accommodated by the Space Transportation System.

Question 17a: Dr. Edelson, are the only starts that can be approved "international" projects?

b. In light of the fact that the shuttle manifest is already overbooked, why did the U.S. agree to launch four of the five satellites in the Global Geospace Science (GGS) Mission?

Couldn't these satellites be launched on expendable launch vehicles — like Ariane?

c. What is the total estimated cost of the U.S. participation in the GGS program -- please break that number down into the cost of the hardware, launches, and operations?

d. What are the tentative launch dates for each of the five satellites:

Answer 17a: The 1958 Space Act specifically instructs NASA to conduct its activities "so as to contribute materially to ... cooperation by the United States with other nations and groups of nations." We have followed this mandate from NASA's inception and have concluded well over 1000 agreements with some 135 countries and international organizations. These agreements cover a wide range of activities from the sharing of data to the development of complex space hardware.

NASA, and the nation, benefit substantially from these international endeavors, scientifically, financially and politically. One of the guiding principles that we have followed for cooperative projects is that they must be of mutual scientific benefit. Just as important, our foreign partners share the costs of projects thus providing hardware and other support that we would otherwise have to fund ourselves or do without. This cooperation clearly enhances the scientific return by allowing us to work with the best expertise in the world and by providing us with access to programs being conducted by other countries which are relevant to our work. A third intangible benefit is the strenghtening of relationships with friends and allies abroad.

In formulating our program every year, we go through a comprehensive planning cycle. Our planning activities involve internal discussions together with extensive consultation with our advisory committees such as the Space Science and Space Applications Boards, the Space and Earth Science Advisory Committee, the Space Applications Advisory Committee, and the Life Sciences Advisory Committee. These committees provide guidance on major new program thrusts, priorities for new starts, and recommend the appropriate balance between new starts and other activities such as research and analysis. We attempt to take as many of these views as possible into account when we prepare our budget proposals.

New starts are considered primarily on the potential benefits of the science and/or applications content of each candidate program. For example, as our space exploration has progressed over the years, we have gathered a large amount of data from the many missions. Usually these have been specific measurements that do not allow us to study the problem as an ongoing system. Thus, we are now to the point where we need precise and simultaneous data to begin to understand some of the intricacies of interrelated systems such as the environment of the earth. Because of the magnitude of our mission to understand the Earth's environment, discussions were undertaken with colleagues in Japan and Europe for possible collaboration in this large size and complex program which is far beyond our limited resources. In addition to U.S. leadership in this program, our science community will have access to all the data acquired from all the orbiting spacecraft, regardless of the country of origin.

In summary, programs involving international partners will continue to be an option that we will consider as appropriate to the given circumstance.

b. Two of the five missions, Wind and Polar are U.S. spacecraft with U.S. instruments (including 25 percent foreign Co-I hardware participation) and are planned to be launched by NASA. NASA is also planning to launch Geotail spacecraft, ESA's SOHO spacecraft, and one of four ESA cluster spacecraft in order to achieve a cooperative bilateral arrangement with Japan and ESA. Investigations/instruments on all of these spacecraft are shared.

All GGS spacecraft were baselined for STS but can be procured as ELV compatible; a decision which is presently under consideration at NASA.

c. Total Estimated GGS cost in (RY$M) are:

Hardware	334
Mission Operations and Data Analysis	65
Launches for Wind & Polar Including Upper Stages and STS Additive Costs	77
Networks, Communications & Data Systems	29
Total	505

d. The GGS planned launch dates are:

Wind	March 1992
Geotail	March 1992
Polar	September 1992
Cluster	1993
Cluster (3 spacecraft launched on an Ariane)	October 1994
SOHO	October 1994

Question 18: TOPEX -- This new start was approved last year as a joint mission with the French. However, it also was related to the proposed Navy program called N-ROSS that has been cancelled in the FY 1988 DOD budget request.

a. What impact has the cancellation of the N-ROSS program had on the TOPEX/Poseidon mission? Are the French reassessing their participation as a result of this change?

b. What impact will the cancellation have on NASA's development of the scatterometer -- the key instrument that was to fly on N-ROSS - and what alternative vehicles are being considered for flight of the scatterometer?

c. When will you be able to provide this Subcommittee with a firm plan for the scatterometer?

Answer 18a: Given that the prospects appear quite promising for securing a ride for the NASA Scatterometer (NSCAT) on an Air Force satellite (see answer to 18b(2) in the same general time-frame as TOPEX/Poseidon, there has been, and should be, no significant impact to our plans for TOPEX/Poseidon. The French are not reassessing their participation as a result of the cancellation of N-ROSS.

b(1). So as to maximize the opportunity for flight of NSCAT on an alternative satellite in the same time-frame as TOPEX/Poseidon, NASA is proceeding with the development of NSCAT on essentially the same time-table as before N-ROSS was cancelled. This approach is especially prudent when viewed from a cost perspective, since all (4) of the major subcontracts were already in place.

(2). The Deputy Secretary of Defense, William H. Taft, IV, has stated in a letter to the NASA Administrator, James C. Fletcher, that Navy continues to need the data that was planned to come from N-ROSS, and that he is interested in examining the possibility of an alternative space vehicle for the flight of NSCAT. Therefore, our emphasis has been on exploring the possibility of a ride on an Air Force satellite. More specifically, we are working together with Air Force and Navy on two options: 1) a Defense Meteorological Satellite Program (DMSP) satellite planned to be ready to launch in December 1990 (the TOPEX/Poseidon planned launch date is December 1991), and 2) a Space Test Program (STP) mission planned for launch in December 1992. Air Force has tasked RCA (their satellite contractor) to conduct feasibility studies for both of these options, and while some pro's and con's for each have been identified, the studies are not yet complete, and thus it is too early to say which option is preferred.

c. The option studies noted in 18b(2) above will not be complete until sometime in May, at which time sufficient information should be available to make a decision as to how best to proceed. Allowing another couple of months for Navy, Air Force, and NASA to finalize an appropriate interagency agreement, NASA should be in a position to discuss its plan for NSCAT in depth by the end of summer.

Question 19: Dr. Edelson, is it true that one of the Space Station's limiting constraints is the stay time of the crew?

What is being done to improve this situation and to overcome the constraint? And why is there no budget increase in FY 1988 to address this constraint?

Answer 19: To date the U.S. operational experience with long duration space missions has been limited to biomedical experimentation conducted on three crewmembers during the 84-day Skylab mission in 1974. The Soviets have flown three cosmonauts for 237 days, the current space endurance record. Both programs experimented with different, though similar, countermeasures to physical deconditioning during these missions. Despite the empirical use of countermeasures, changes in some body systems such as heart, bone, blood, muscle have been observed. These changes have resulted in a significant decrement in physical deconditioning upon return to Earth which required careful reconditioning and rehabilitation of crewmembers prior to return to regular duties.

It is felt that with careful planning and execution of a vigorous research program both on the ground and in flight that changes in human body systems can be first slowed down, then stopped and ultimately prevented without imposing severe penalties on the flight crews, such as 3 to 4 hours daily physical exercises in space.

Work is currently underway utilizing ground based simulation facilities, such as bed rest, to test different types of physical conditioning devices and regimens as potential candidate biomedical countermeasures to space flight deconditioning. Though these models are useful "testbeds" for long duration missions, they cannot be total substitutes to actual space missions. Complementary to these ground based activities are the high quality experiments which await the resumption of STS/Spacelab missions and which will produce a better understanding regarding the mechanisms of the physiological changes experienced in space flight in some but not all of the mentioned body systems. In turn, these findings will help to refine the ground based models which are the only means currently available to the U.S. program to study long term effects of "space deconditioning" in the absence of the Space Station.

Our FY 1988 budget requests for life sciences includes funding for continued research in space biomedical experimentation. Comprehensive program planning for a more extensive program is currently underway, and it is anticipated that increased funding will be required in future years to enhance this important area of research as Spacelab and Space Station flight opportunities become available.

Question 20: In your statement, you indicate that formal Joint

Life Sciences Program Working Groups have been established with the European Space Agency, the Japanese, French and West Germans. Why haven't the Soviets been included in this formal group? Is inclusion of the Soviets part of the U.S.-U.S.S.R. Joint Agreement currently being circulated?

Does the U.S. currently have informal working relationships with the Soviets?

Answer 20: Recently a new U.S.-U.S.S.R. Space Agreement was signed establishing new formal working groups with the U.S.S.R., including one in Space Biology and Medicine. The first meeting was held in August 1987 in the Soviet Union.

In the hiatus between the expiration of the previous bilateral Space Agreement in 1982 and the signing of the current agreement, the U.S. relationship with the Soviets was limited mainly to activities previously agreed to but at a lower level and, therefore, not affected by the non-renewal of the bilateral agreement. U.S. participation in Soviet biosatellite missions is the best example of this type.

Question 21: What is the current participation of the Life Sciences Office in the current Soviet Biosatellite Mission?

Does the Life Sciences Office intend to initiate its own Biosatellite Program with the $2 million per year it receives from the Vitality Package?

What is the relationship between NASA and DOD on this program?

Answer 21: NASA's Life Sciences Division has successfully completed negotiations with the Soviets to fly joint experiments with them on their upcoming biosatellite mission scheduled for launch in late September or early October 1987.

The Life Sciences Division is assessing the feasibility of using a reusable free-flyer capability in its program. This added capability would complement the STS Spacelab program by allowing extended mission duration and special orbits to be reached by this module using either ELV or STS. Such a system would allow the conduct of experiments for longer periods of time in space than currently offered by the Spacelab and years before the Space Station Laboratory is available. Initial results from life sciences community surveys, advisory committee comments, and internal evaluations are highly positive. The Vitality Package resources would be used primarily to support definitive studies and payload development, not to procure a biosatellite.

We also have had informal discussions with DOD regarding the possibility of using the "piggy-back" mode on DOD ELVs launches. The informal response, was positive especially in regard to polar launches where we would be able to conduct radiation biology experiments which are necessary for manned planetary missions.

Question 22: The Soviet Union and Japan have committed to the development of Bioregenerative Life Support Systems -- that are critical to long duration space flight activities and missions.

Does NASA intend to procure such a system. If so, when? If not why not?

Is such a system required if there is to be a manned-Mars mission?

Answer 22: NASA has been performing research directed toward the development of Bioregenerative Life Support Systems since 1980 as part of its Controlled Ecological Life Support Systems (CELSS) effort. To date a feasible approach using crops to regenerate food, air, and water for a human crew has been developed. To test this approach, the program is now developing a large breadboard model of a CELSS system at the Kennedy Space Center.

Current funding levels allow for the continuation of CELSS research but it is not adequate for procurement of a bioregenerative life support system.

Whether a CELSS is to be included in a manned-Mars mission will depend upon the results of the tradeoff analysis performed during the definition phase of the flight system. In general, the use of a CELSS should be favored for missions whose duration approaches three years or if a Moon or Mars settlements are planned for, and where resupply of life support elements, such as food, water, air, is either too costly or not feasible.

Question 23: A critical element of a Space Station life science program is a centrifuge. Does NASA intend to procure a 1.8 meter centrifuge for inclusion into the Space Station at initial operation capability?

Is OSSA also requesting that the Space Station be "scarred" to accommodate a 4 meter centrifuge?

Answer 23: The National Academy of Sciences and the Life Sciences community have strongly advocated the availability of a large diameter centrifuge on the Space Station for the conduct of high quality life sciences research. Current Life Sciences planning includes the development of a 1.8 meter diameter centrifuge for possible inclusion into the Space Station. At this time, funding for the centrifuge does not exist in the Life Sciences budget. If funding does not begin in FY 1989 it is unlikely that the centrifuge will be operational at the initial operation capability of the Space Station. Recently a congressional decision was made to prohibit the 1.8 meter centrifuge from being installed in the U.S. lab aboard Space Station. A study is currently underway to determine whether alternate facilities (a node) are acceptable.

A previous study suggested the option of placing the 4.0 meter centrifuge in an attached module; OSSA has requested the Space Station Office to include the study of the large centrifuge accommodation in its RFP.

Question 24: Why doesn't the FY 1988 NASA Space Science and Applications budget augment the suborbital program to ensure flight opportunities to NASA investigators and researchers?

Answer 24: All the suborbital program budgets were carefully evaluated following the Challenger disaster. The Sounding Rocket budget and related science activities were augmented with $4.2 million of the Vitality Package funds in order to accommodate increased scientific activity within the Sounding Rocket program. The Vitality funds were preferentially used to support scientific activities that were directly impacted by the Challenger disaster. The balloon program, while not directly impacted by the Challenger accident, is recognized to have potential for significant scientific contributions, so its budget is undergoing continuing evaluations as a candidate for future augmentations.

Question 25: Does NASA intend to replace the Spartan or will this program be terminated? What options are being considered to provide flight opportunities for small science payloads and instruments? Do these payloads require Priority Status and Reflight Guarantees to ensure a place on the manifest?

Answer 25: The Spartan program is currently under review in light of the significant reductions in flight opportunities on the Space Shuttle. It appears evident that the Spartan program as we know it today will be significantly changed. Options currently being considered to provide flight opportunities for small science payloads and instruments are: to increase the number of sounding rocket and large balloon flight opportunities and to press for early opportunities for small payloads on the Space Station. In addition, we are currently exploring possibilities to fly small payloads in "super gas can" type containers that could be flown on Shuttle or Scout type vehicles.

Priority Status and Reflight Guarantees to ensure a place on the STS manifest would be extremely difficult in light of the demands for major mission and DOD launch slots. Whenever possible, small payloads will be accommodated.

Question 26: How many Spacelab missions are currently on the Shuttle manifest? How many were there on the manifest prior to the Challenger disaster? Doesn't this reduction in Spacelab flights adversely impact the utilization of the Space Station? Are any interior measures being assessed that would provide enhanced flight opportunities prior to deployment of the Space Station?

Answer 26: There are presently 11 Spacelab missions in the manifest through 1994. Four of these are partial missions in that they require from 1/2 to 2/3 of the Shuttle cargo bay. The other seven are dedicated Spacelab missions. Of these, one is a DOD flight, one is the German D-2 mission, and one (SL-J) is half reimbursable by the Japanese. The other four are dedicated NASA missions.

Prior to the Challenger accident, there were twenty-eight Spacelab missions through 1990. Of these, 12 were dedicated Shuttle missions and 16 were partial Shuttle payloads. These include the dedicated German mission (D-2), the DOD Spacelab mission, and SL-J which is half Japanese. The remaining are all NASA missions.

This reduction will not necessarily adversely impact the utilization of Space Station. What will be impacted will be the science that is flown on Spacelab. In some disciplines, particularly materials science and life science, we will necessarily be performing science on the Space Station that would have been completed on Spacelab.

We are continuing to assess other means of accommodating our science prior to deployment of the Space Station either through flights on expendable launch vehicles or screening of what is being planned to allow the highest priorities to be carried out on our very limited opportunities.

Question 27: Could you please inform the Subcommittee of the purpose of the NASA Vitality program and the major initiative in each program area being supported by this program?

How much money is being requested in FY 1988 for the Vitality program? What is the level of activity in FY 1988?

Answer 27: Details about the proposed use and distribution of "Vitality Package" funding are contained in the enclosed White Paper.

March 1987

Vitality Package

The purpose of the NASA Office of Space Science and Applications (OSSA) "Vitality Package" is to provide additional funds to the research community, particularly universities, to help researchers maintain active research programs during the present major hiatus of flight opportunities. To be effective in dealing with the current situation, such an infusion of funds must be directed to activities which can provide immediate research opportunities and yet which do not lead to a major, long-term obligation which OSSA may not be able to sustain once normal payload development and flight opportunities resume. The vitality program focusses on the two major areas which are most likely to produce short-term results: 1) continuation of basic research, analysis of data from previous flight missions, technology development in preparation for future flight missions, and continued operation and data retrieval from currently operating spacecraft; and 2) increased activity in the suborbital program as a means of providing near-term flight opportunities, allowing continuity in research for several science disciplines which can effectively use aircraft, balloons, and sounding rockets.

The Research and Data Analysis part of this enhancement will be used to support a variety of activities. The planetary exploration program has been particularly hard hit by the Challenger accident and subsequent the decision to cancel the flight of the Centaur upper stage on the Shuttle. There is a substantial backlog of planetary spacecraft awaiting flight opportunities aboard the Space Shuttle or on expendable launch vehicles (ELV's) if they can be obtained. There is great concern in the planetary community concerning prospects for the future. The planetary portion of the vitality package will focus on advanced technology development (ATD) for the Mariner II class of future spacecraft which are a major thrust of the long-term program strategy defined by the Solar System Exploration Committee. Near-term focus is on planning and mission development activities in support of the Comet Rendezvous Asteroid Flyby (CRAF) mission now under consideration as a major new start.

Archival results from previous flight missions constitute a major resource which can be mined to obtain important new scientific results. For example, data from the previously flown astrophysics missions such as the High Energy Astrophysical Observatories (HEAO), the International Ultraviolet Explorer (IUE) and the Infrared Astronomical Satellite (IRAS) are available and there is much interest in combining data from the various missions. More than 200 letters of intent were received in response to the recently issued Space Science and Applications Notice for Astrophysical Multispectral Data Analysis. Spacelab-2 data analysis will also provide continued research opportunities for astrophysics as well as the space plasma physics community. Within the Earth science community, loss of Shuttle flights means an increased need for continued operation and expanded data analysis and Guest Investigator programs for satellites such as Nimbus, the Solar Mesospheric Explorer (SME), the Dynamics Explorer (DE), the International Cometary Explorer (ICE), and others. The research areas of materials science and life science which are critically dependent on Shuttle flights for access to space will use vitality package funds for work on enabling technology development and supporting research in preparation for future flight activities. New approaches to carrying out flight experiments such as using augmented Discover capsules for doing experiments in space medicine and biology are also being investigated.

The suborbital program enhancements will provide extra support for the ongoing aircraft, balloon, and rocket programs. By a variety of approaches (e.g., increasing the C-141 hours available, by converting smaller balloon payloads to larger flight facility class payloads able to accommodate guest investigators, and by increasing sounding rocket availability) new flight opportunities can be made quickly available to the research community allowing continued data gathering to help keep research groups active and provide ways of obtaining new results. Accelerated development of instrumentation for flight on facilities such a the DC-8 will permit geological studies using synthetic aperture radar (SAR), flight of ozone and atmospheric or oceanic species monitors, as well as biospheric experiments over the Amazon, malaria research, and coordinated interdisciplinary biogeochemical studies. Expanded availability and use of drop towers will allow new materials processing research. Sounding rocket opportunities will provide for research in space plasma physics as well as a variety of astrophysics experiments in high energy and solar physics.

In FY 1988, we have requested a total of $25 million for the various activities in the Vitality Package.

In summary, this Vitality Package represents a modest infusion of funds intended to help support a broad research community for a period of 3-4 years until Shuttle flights resume. Such activities should be particularly important for allowing graduate students to carry out research programs in the near term and for keeping university research groups viable. As Shuttle and ELV launch opportunities are restored, the extent to which the basic research and analysis and suborbital programs need extra funds will decline and these research activities can then return to their normal funding level.

Question 28: Dr. Edelson, the FY 1988 budget request for Space Science and Applications is $1.5 billion which is 15.9 percent of the total budget request and 41.6 percent of the Research and Development Budget Request.

For the sake of comparison, Space Science and Applications was 19 percent of the total FY 1986 budget and 56 percent of the FY 1986 R&D budget. In FY 1987, Space Science and Applications was 18.5 percent of the overall budget and 49.6 percent of the R&D budget.

Quite clearly, Space Science and Applications is losing in the NASA Research and Development Budget despite the fact that the FY 1988 request represents a 38.5 percent increase over the FY 1986 level of funding.

Why is NASA unable to get any real growth in the space science and applications budget when it is clear it can get increases in the Space Station program, in space transportation and capability development, in aeronautics and space technology--the three principal R&D accounts besides space science?

Answer 28: Year-to-year changes in the OSSA program are largely driven by the phasing of funding requirements for the major flight projects. The $45 million reduction from FY 1987 to FY 1988 reflects the ACTS termination, the phasing down of major development projects (e.g., Magellan, UARS, and Galileo) offset in part by increases for the GGS project and TOPEX, as well as increases in the Research and Analysis program. If GGS is approved by Congress as an FY 1988 new start, and other elements of the OSSA request for FY 1988 are also approved, there will be real growth in FY 1989 above the FY 1988 level as a result of the normal runout of the OSSA program proposed in this year's President's Budget.

Question 29: In November 1986, the NASA Space and Earth Science Advisory Committee (SESAC) issued a report entitled "The Crisis in Space and Earth Science: A Time for a New Commitment." Dr. Lanzerotti, the Chairman of this Committee, is here today to highlight the findings of the report.

The Report warned that America's space and earth science program is in a crisis--with the U.S. preeminence in these fields "now in question." The Report went on to say that there were more opportunities for science in space than could be accommodated by the present NASA budget and that "either progress in all of the space and Earth sciences must be delayed or some of the disciplines must be assigned a higher priority to proceed at an optimum pace."

What does NASA intend to do in response to this report? And hasn't the Challenger disaster exacerbated a situation that was a crisis even before the accident occurred?

Answer 29: As pointed out in the Space and Earth Science Advisory Committee (SESAC) report, the Challenger disaster has certainly exacerbated a situation that was a crisis even before the accident. The Office of Space Science and Applications (OSSA) recognizes the need to pursue many of the specific recommendations in that report. Several of the recommendations are specifically aimed toward more effective management of the funds, people, and institutions currently at the disposal of OSSA. Where appropriate, recommendations toward release of Announcements of Opportunity, funding of consortia proposals, and restraint on starting Phase B projects will be implemented. Certainly much of this restraint and reassessment is currently occurring during the hiatus in Shuttle flights. Other SESAC recommendations stem primarily from thoughts that NASA must confront how broad a program is feasible to maintain. Here too, we firmly agree with SESAC and recognize that such wide-ranging decisions should be made on the basis of the broadest possible discussion, not only in Congress but within the Executive Branch and the scientific community as well, and should not be made by NASA alone.

Question 30: It was recently reported in a trade journal that 61 percent of the Office of Space Science and Applications budget will go to industry in FY 1987, compared to only 15.8 percent for universities.

Are those levels consistent with the last ten years, or is there a marked trend that more and more NASA space science dollars are going to industry and not to universities?

Answer 30: In FY 1978, an estimated 18 percent of the Office of Space Science budget went to universities. About 12-14 percent of the OSSA budget in recent years has gone to universities. The recent trend is for FY 1986 (12 percent), FY 1987 (13 percent), and proposed FY 1988 (14 percent).

Question 31: Dr. Edelson, are discussions currently underway within NASA to transfer the Space Station platforms from the Space Station Office to the Office of Space Science and Applications?

Answer 31: Recently, an examination was made of the pros and cons of transferring the Space Station platforms to the Office of Space Science and Applications. It was determined that the benefits that accrue to developing platform common modules as part of the Space Station program warrant a continuation of that approach. Our payload programs, the Earth Observing System for the Polar Orbiting Platform, and the Advanced X-ray Astrophysics Facility for the Co-orbiting Platform, are coordinating their requirements through the Work Package 3 Space Station program at the Goddard Space Flight Center.

Question 32: In the very near future, the Soviet Union intends to launch a space science module containing astrophysics experiments and instruments and connect it to the MIR Space Station. Many of these instruments are being supplied by principal investigators in Western European nations.

Is the U.S. the leader in space science and applications?

What affect do these initiatives by the Soviets have on the perceived status of the U.S. space science program?

Why is it the Soviets appear capable of achieving a credible launch schedule and acting as reliable partners while the U.S. does not?

Answer 32: The U.S. has many important programs now underway such as Hubble Space Telescope (HST), the Galileo mission to Jupiter, the Upper Atmospheric Research Satellite (UARS), the Gamma Ray Observatory, Magellan, the Mars Observer, the Ocean Topography Experiment (TOPEX), and the various elements of the International Solar-Terrestrial Physics (ISTP) Program which, when they are launched, will ensure preeminence across many space science disciplines for a very long time. Clearly, with the hiatus in launches, we are now at a particularly difficult time. However, once the Space Shuttle is flying again, and we have reestablished our launch capabilities, U.S. leadership in space science research should again be assured. The particular initiatives by the Soviets do not affect our program. Our programs have resulted from a lengthy and intensive planning effort carried out in conjunction with the U.S. scientific community. Each of these programs is expected to lead to major and unparalleled advances in their respective fields.

The U.S. has had a long history of being involved in international programs which have led to many successes. The enclosed table gives a number of examples of such successes. Despite some recent problems, the U.S. has, in fact, been an extremely reliable partner. TOPEX (approved in the FY 1987 budget), and the ISTP program (U.S. participation in the Japanese Geotail mission and the European SOHO/Cluster missions approved in the FY 1987 budget and the U.S. Global Geospace Science program proposed in the FY 1988 budget) are both major international programs. The fact that we are still proceeding with such major international efforts, and that active discussions are now underway concerning a number of potential future cooperative programs, is the clearest possible statement concerning our perceived reliability as a partner.

Mission	Discipline/Purpose	Participants
Past Missions		
AMPTE	Space Plasma Physics	US, Germany, UK
ANS	UV and X-ray Astronomy	Netherlands, US
Ariel I, II	Cosmic Ray Physics, Space Plasmas, other disciplines	UK, US
COSMOS	Life Sciences	USSR, US
HEAO-3	Cosmic Ray Physics	US, Denmark, France
Helios	Heliospheric Physics	Germany, US, Italy, Australia
IRAS	IR Astronomy	US, Netherlands, UK
ISEE-1, 2, 3	Space Plasma Physics	US, ESA, France, UK, Germany, Netherlands, Italy
IUE	UV Astronomy	US, ESA, UK
OAO-3	UV and X-ray Astronomy	US, UK
OGO-2 and 4	Aeronomy	US, France
OSO-8	Solar Physics	US, France
Search and Rescue	Communications	US, USSR, Canada, France
SMM	Solar Physics	US, Netherlands, UK, Germany
Spacelab-1	Multidisciplinary	ESA, US, Canada, France, Japan
Spacelab-2	X-ray Astronomy, Solar Physics	US, UK
Spacelab-3	Multidisciplinary	US, India
TIROS N	Meteorology	France, UK
Nimbus 7	Oceanography and Meteorology	UK
Present Missions		
COSMOS 1987	Life Sciences	US, USSR
Galileo	Jupiter Investigations	US, Germany
GRO	Gamma-ray Astrophysics	US, Germany
HST	UV/Optical Astronomy	US, ESA
Magellan	Radar Mapping of Venus	Australia, Canada, France, UK
ROSAT	X-ray Astronomy	Germany, US, UK
TSS	Multidisciplinary Applications	US, Italy
UARS	Atmospheric Physics	US, UK, France, Canada
Ulysses	Heliospheric Investigations	US, ESA

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of: XC:MDD:C-21656f

OCT 2 1987

Honorable Donald W. Riegle, Jr.
Chairman
Subcommittee on Science, Technology
and Space
Committee on Commerce, Science
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

Enclosed are the final responses to written questions resulting from the April 29, 1987, hearing at which Mr. Myers and Mr. Stofan testified on NASA's FY 1988 Space Station budget request.

This information completes the material requested during that hearing.

Sincerely,

John J. Madison
Acting, Chief
Congressional Liaison Branch

Enclosures

Responses to written questions submitted by Chrm. Riegle.

Cost Increase

Last April, when NASA testified before this Subcommittee, the estimated cost of the Space Station program was $8 billion — today it is $14.5 billion for the full-up NASA program, $16.0 billion for the 2-phase program, or $12.2 billion for a Phase I only program. Let me also note that the FY 1988 budget request for the Space Station program was based on an $8 billion program.

Question 1: What are the reasons for this cost increase and why did it take over three years for NASA and OMB to come up with these figures?

Answer 1: The original preliminary cost estimate for the Space Station was made approximately 18 months before the definition and preliminary design (Phase B) contractors were brought on board. Our current estimates are based on our best information as well as that of the Phase B contractors. Only recently were we able to do the in-depth review of the ground-based support infrastructure. The increases in the cost estimates are as follows:

(1) increased hardware costs in recognition of user accommodation and operational efficiency;
(2) increase of identified program specific facilities;
(3) inclusion of Rogers' and Phillips' management recommendations;
(4) inclusion of basic engineering and institutional support;
(5) additional program reserve.

Question 2: How could NASA have underestimated the cost of the ground based support infrastructure by $3.6 billion or nearly 93% of the estimated cost?

Answer 2: The original estimates were primarily based on parametric costs associated with the hardware as envisioned at the time. Only during the recent cost assessment review were we able to obtain a full understanding of the ground-based support infrastructure required to support the hardware development. The kind of SE&I activities required to support a permanent space facility are new to the agency. This kind of project has never been attempted before. As such, developing early cost models in the absence of historical precedent was a difficult task. In addition, the Phillips report on Space Station and the Rogers Report on the Challenger accident mandated that NASA significantly modify its SE&I procedures. In response to these studies and the challenges in SE&I posed by the Space Station Program, the Space Station Office established the Program Support Contract (PSC) at a cost of about $.7 billion dollars in real year dollars.

Question 3: How can one now expect to find significant savings in the program when one realizes that $6.1 billion of the $6.5 billion increase in the NASA proposal was for the ground based infrastructure account and the program reserve account -- not for hardware?

Answer 3: The original preliminary cost estimate for the Space Station was made approximately 18 months before the definition and preliminary design (Phase B) contractors were brought on board. Our current estimates are based on our best information as well as that of the Phase B contractors. Only recently were we able to do the in-depth review of the ground-based support infrastructure. This represents a detailed understanding of the development of the operational facilities and the engineering support NASA must provide to fulfill basic requirements. Since the Space Station has a life-span of at least 30 years, an initial investment for the program was considered to provide efficiency during Station operations. The ground-based support infrastructure includes provision for government furnished equipment.

Question 4: Realizing the fact that not one piece of metal has been cut for this program and that OMB has cut the proposed NASA Space Station budget request in each of the last two years (from $580 million to $410 mission in FY 1987), how can the members of this Subcommittee embrace another Administration cost estimate next fall?

Answer 4: As background, it should be noted that the Office of Management and Budget recognized the fact that the Space Station Program was facing both a start-up delay and a schedule slip and took this into account when they cut the proposed Space Station budget request for the last two years. The in-depth NASA cost assessment and analysis of the program -- completed in early 1987 -- is currently being reviewed by the National Research Council (NRC).

The results of the NRC's analysis will be used to determine if any changes in program approach and content are warranted. We have welcomed this review and believe the results will be helpful in establishing a commonly understood baseline for the Space Station Program.

Space Station Budget

A term of the trade has been introduced in the NASA and OMB description of the NASA Space Station budget -- a three year rolling commitment

Question 5: Would you please explain to the Members of the Committee what three year rolling commitment is and how binding is this commitment?

Answer 5: The proposed three year rolling commitment has not been worked out in detail. The basic concept is that the program budget would be established for a three year period with agreement among NASA, OMB and the Congress. Each succeeding fiscal year would require a new budget to be established for the succeeding third year.

The commitment to the budget year and succeeding two years appropriations is intended to provide program and budget stability, but does not preclude changes to the levels of funds already appropriated if the Congress believes such changes are warranted.

Question 6: Is this commitment between NASA and OMB? Does NASA intend to get a similar commitment from the Hill?

Answer 6: The proposed commitment would be among all parties--within the Executive Branch and between the Executive Branch and the Congress.

Question 7: Is this commitment binding regardless of the cost and configuration of the final Space Station program -- two pieces of information that the Committee will not have until the FY 1989 budget submission?

Answer 7: The proposed legislation to provide for the three year rolling commitment is intended to be submitted with the FY 1989 budget recommendations of the President. The cost and configuration of the Space Station will have been extensively reviewed by that point, and a final recommended position will have been established by the Administration.

2-Phase Program

Based on information supplied to the Subcommittee, the Phase I cost estimate of $12.2 billion results from delaying specific activities until Phase II -- which may or may not be initiated -- and subtracting the estimated value of these activities ($2.3 billion) from the $14.5 billion NASA program estimate. In particular, the co-orbiting platform (-$300 million), the solar dynamic power system (-$1 billion), the dual keel structural trusses and upper and lower booms (-$600 million), and the servicing facility and mobile base (-$400 million) have been deferred or will be terminated depending on the results of the on-going programmatic review.

Question 8: For the record, would you please provide the Subcommittee with a copy of the NASA Space Station budget for Phase I, as well as a separate budget estimate for Phase II.

Answer 8:

	($ in Billions)	
Space Station Development	1984 $	1988 $
Revised Baseline-Phase I	10.9	13.0
Phase II (1991 start)	3.3	4.0
Engineering & Institutional Spt.		
Revised Baseline-Phase I	1.3	1.6
Phase II (1991 start)	.5	.5
Total Base and E & I	16.0	19.1
Total 0 / I	12.2	14.6
Total 0 / II	3.8	4.5

Question 9: At present, what are your best cost estimates for each of the major components of the Phase I program:

(a) cost of one habitation module
(b) cost of one material processing/life sciences module
(c) cost of a node
(d) cost of 75 kW of power and the management distribution program
(e) cost of one polar platform
(f) cost of the horizontal boom
(g) cost of one Flight Telerobotic Servicer

Answer 9:

The current estimates for contractor costs for these items are:

Flight Element	FY 84 $ in Billions Total	FY 88 $ in Billions Total
Hab Module	.4	.4
MP/LS Module	1.2	1.4
Node	.3	.4
75kw Power	.8	1.0
Polar Platform	.2	.3
Horizontal Boom	.5	.6
FTS	.2	.3

These estimates, except for the FTS, do not include unallocated in-house development costs such as system engineering or program management, or related development costs for sub-systems located within the pressurized modules, such as communications, ECLSS, power distribution, etc. The FTS cost estimate reflects the total definition, development, test and production effort.

Question 10: What are your best cost estimates for each of the major support contracts and what are the proposed lifetimes of these contracts:

a. Program Support Contract (systems engineering and integration)
b. Technical and Management Information System Contract
c. Software Support Environment Contract

Answer 10(a): The cost of the Program Support Contract is approximately $.7 billion in real year dollars and spans 9 years.

(b) The cost of the Technical and Management Information System contract is approximately $3 billion in real year dollars for eight years.

(c) The cost of the Software Support Environment contract is approximately $3 billion in real year dollars for six years.

Question 11: Do these cost estimates for the habitation and material processing modules assume they are fully equipped and operational?

Answer 11: The Space Station cost estimates include basic element equipment, subsystem equipment and functional outfitting. They do not include facility class user equipment or unique user equipment such as microscopes, centrifuges, and furnaces.

Question 12: What is the estimated value of the scientific equipment and instruments that will be incorporated into the Space Station budget? Is that part of the Space Station budget or the Office of Space Science and Applications Budget?

Answer 12: There are no costs for scientific experiments or instruments included in the Space Station budget. These costs are borne by the respective users of the Space Station. The Office of Space Science and Applications has identified candidate experiments but specific plans have not been finalized.

Question 13: What are NASA's best estimates of the following costs that are not part of the base program:

(a) transportation requirements;
(b) crew escape rescue vehicle;
(c) annual operating costs; and
(d) facilities construction, etc.

Answer 13(a): The marginal costs of transportation requirements are approximately $0.8 billion for 19 flights in FY 1988 dollars.

(b) We now have underway a Phase A study to determine if the Crew Emergency Return Vehicle is needed. Requirements have not been definitized but the current cost estimate is approximately $1-2 billion in FY 1988 dollars.

(c) When a mature operational state is reached (ca. 2000) the estimated annual operating costs are expected to be approximately $1.3 billion in FY 1988 dollars. This does not include STS, communications and tracking, or R&PM costs.

(d) The construction of facility costs in direct support of the Space Station as defined at this time are approximately $200-230 million in FY 1988 dollars.

Budget Shortages

In a recent analysis conducted for this Committee by the Congressional Budget Office, "The 1988 Budget and the Future of the NASA Program," it was noted that "in order to continue NASA's agenda at its pre-accident level, the cost of program additions in space transportation, space science, and the Space Station would increase the NASA budget by $14 billion above the CBO baseline for fiscal years 1988 through 1992."

In these times of serious fiscal constraint, the only way the civil space program will secure this level of funding, i.e., become a high budget priority, is if the civil space program is perceived as a national priority.

Question 14: Is the civil space program, in particular the Space Station program, a national priority and why should the Congress increase funding for these activities?

Answer 14: The civil space program is a particularly important national endeavor. It is of the highest priority because it contributes directly to our country's economic and political strength. Through the development of new technologies, the discovery of new knowledge and the support of commercial enterprises the civil space program manifests its considerable value. And by exploring the vast world of space extending mankind's presence to the stars, the program reflects a deeply-rooted human need to better understand the universe and the very small part of it called Earth.

Congress should consider the funding requirements for the civil space program in light of its substantive practical and symbolic values, and the desirability of U.S. leadership in space. We believe that Congressional support is clearly warranted and that the Space Station will provide an important component of U.S. leadership in the future.

Question 15: What are NASA's and OMB's budget projections for the next five years? Can these projections accommodate the Space Station project, a mixed fleet, a robust space science program, and advanced solid rocket motor program, an advanced launch system R&D program, and a competitive aeronautics program? Or are we buying into a lot of programs that we ultimately will not be able to fund?

Answer 15: A budget projection for the next five years which incorporates both approved programs and prospective future new programs requires the formulation of may programmatic and resource priority assumptions, particularly in the 1991-1993 period. There is no predetermined allocation for NASA programs in the future budgets of the U.S. Government.

Requests For Proposals (RFP'S)

Last week, after a nearly 6-month delay, NASA was given permission to release the RFP's for Phase C/D (hardware/development) of the Space Station program. I would note that these RFP's ask potential contractors tp bid on both the full-up program and the phased program.

Question 16: Would you please tell the Subcommittee what the proposed schedule is for the review of these proposals and the final award of the Phase C/D contracts.

Answer 16: The request for proposals (RFP's) were released on April 25, 1987, and the revision detailing the requirements of a second proposal for the phased program on May 15. The proposals are due in on July 1 and July 28, respectively. A 90-day period is scheduled for proposal evaluation. Source selection is planned on October 30 with final award of the contracts on December 13.

Question 17: To what extent could this process be delayed or impacted by the next round of White House Space Station negotiations.

Answer 17: We do not expect any delays in awarding the Space Station hardware contracts.

Question 18: Are there any pre-conditions that must be met before Phase C/D contracts are awarded? E.g., does there have to be final White House agreement on the cost, configuration, and schedule as well as a signed International Government Agreement (IGA) and Memorandum of Understanding (MOU)?

Answer 18: There are no pre-conditions that must be met before the Phase C/D contracts are awarded.

Question 19: If the Phase C/D awards slip, what are the potential program savings in FY 1988? E.g., if no awards can be made in January or February of 1988, why should this activity be fully funded?

Answer 19: We expect final award of the contracts in December 1987. A slippage of 1-2 months in final contract award dates would not result in any significant change in funding requirements because -- to meet our commitment of a March 1994 first element launch -- we plan to minimize any front end schedule delays by authorizing initiation of work prior to final contract awards, judicious use of overtime and increased contractor staffing levels.

Question 20: Can any firm bid for a Phase C/D contract, or to be eligible did a firm have to participate in the Phase B (design study and definition) activities?

Answer 20: The competition is completely open. Participation in Phase B is not a prerequisite for bidding any of the Phase C/D contracts.

Question 21: Will there be four Phase C/D awards?

Answer 21: There will be four Phase C/D awards, one for each work package.

Question 22: To what extent are the reduction of estimated costs, incorporation of automation and robotics or commercial risk taking factors in the evaluation of the Phase C/D proposals?

Answer 22: The RFP's encourage the contractors to propose ways of reducing the estimated cost of the Program, encourage commercial participation in the program, and make clear the importance of incorporating automation and robotics technologies.

FY 1987 Funds -- Frozen or Unfrozen

Pursuant to the most recent communications between the Appropriations Committees and NASA concerning the release of the RFP's, one is left with the impression that $150 million of the FY 1987 funds available for the Space Station program are still frozen.

Question 23: Is that a correct interpretation of the situation, and what is the current status of these funds?

Answer 23: $60 million of the $150 million was released July 15, 1987. Congress still holds the portion of funds which are required for the prime development contracts which are planned to begin in November 1987. The full amount of FY 1987 and FY 1988 funds will be required in FY 1988 in order to maintain the current schedule.

Question 24: Will any of these monies be available to NASA in FY 1987 for any of the support contracts (TMIS, SSE, or PSC) and for any of the hardware contracts?

Answer 24: As stated in our answer to question 23, $60 million of the $150 million has been made available to support Space Station Program requirements in FY 1987. That work includes the support contracts as well as other supporting development work at the NASA Centers.

Question 25: Does NASA have funds available for the SSE and the TMIS contracts in FY 1987 from the program's Definition Account? What is the current situation with the PSC contract -- are there any funds available?

Answer 25: The FY 1987 definition budget includes funds for both TMIS and SSE. The Program Support Contract which was awarded to Grumman in July 1987 is funded with FY 1987 development funding.

Question 26: Which of the support contracts are most critical for the Space Station programs?

Answer 26: All three contracts are important to the Space Station Program. They represent essential long lead capabilities that must be in place and functioning prior to entering the development phase of the Space Station. These contracts are essential to the orderly progression of the Program.

Question 27: If these issues are not resolved in FY 1987, will the Space Station program encounter a delay in schedule?

Answer 27: The Program will require the balance of the FY 1987 funds and the FY 1988 funds to maintain the current schedule.

Winners and Losers

One could argue that the 2-Phase Program has resulted in winners and losers among NASA centers as well as among the scientific disciplines. Hardest hit are the Lewis Research Center and the Goddard Space Flight Center which were intimately involved with the solar dynamic power system and the space sciences. Let's talk a little if we can about both of these areas.

Power

Question 28: First, in finally agreeing upon 75 kW of power for the Space Station instead of 87.5 kW, why has NASA abandoned solar dynamic power -- one of the key advanced technologies to be proposed for the Space Station -- and the concept of a hybrid power system (a system consisting of both solar dynamic and photovoltaic power).

Answer 28: The development of the solar dynamic power system will be examined for future enhancements. A technology program and feasibility demonstrations will be carried out during Phase I in order to be able to develop a Space Station solar dynamic power system in the future. NASA will support continued technology development and testing in order to ensure that a mature solar dynamic system is available if a decision is made to increase the available power on board the Space Station.

Question 29: If NASA required more than 75 kW of power, would NASA add additional photovoltaic power or solar dynamic power.

Answer 29: NASA expects to use the solar dynamic power technology to meet significant increases in power demand over the revised baseline program's planned 75 kW power level. The Revised Baseline Configuration will also be able to accommodate additional photovoltaic power units.

Question 30: Is NASA planning on scarring the Space Station for solar dynamic power during Phase I? What would it cost to scar the system for solar dynamic?

Answer 30: We plan to scar the Space Station power management and distribution system for 175 kW of total power. Most other aspects of the Station's power system will be scarred for an increase to 300 kW. The scarring will be independent of the type of power module added.

Question 31: Does the recent agreement to increase the power rating from 50 kW (the White House recommendation) to 75 kW (the Congressionally mandated) increase the cost of the Phase I program by $250 million? Does it eliminate the option of more power being added in Phase II?

Answer 31: The cost of the increased power level will be absorbed by the program. We are at present investigating the possibility of some reprogramming or taking this amount out of the reserve.

The increase in Phase I power level does not eliminate the potential option of adding more power in Phase II.

Science

Question 32: Why has NASA delayed the co-orbiting platform until Phase II and included the polar platform in Phase I when it is clear there would be a servicing capability for the former and not for the latter? Also, payloads could be retrieved and returned to Earth from the former and not the latter?

Answer 32: It should be recalled that the types of user accommodations to be provided by Space Station, and their phasing, are determined mainly by the requirements of the user community. There has been extensive planning within the user communities over the past several years for a multinational instrument complement to be flown on both the NASA polar platform and the polar platform planned to be provided by ESA. For the instruments planned to be provided by NASA, provisions are being made in future budget years for initiation of instrument development in a timely manner to support the projected polar platform launch date(s). Similar planning is taking place in other countries. Part of this instrument complement is meteorological instrumentation to be provided by NOAA.

With the planned launch in late 1995 of the NASA polar platform, the first servicing of this platform would be no earlier that 1998. A servicing capability would need to be developed by that time. One possibility would be to develop a shuttle capability to meet that requirement. Another possibility would be to develop an Automation and Robotics (A&R) system to accomplish this task.

The primary instrument candidate for the NASA co-orbiting platform has been AXAF. It has not yet been determined whether AXAF would utilize Space Station provided co-orbiting platform modules or a dedicated free-flyer bus. This will be clear when a final determination is made regarding the development and configuration of the AXAF system.

Question 33: Doesn't the elimination of the upper and lower boom compromise the scientific value of the Space Station and the ability to attach scientific or commercial payloads? (The phased program initially reduces the number of attachment points from 5 to 2.)

Answer 33: At this time, there are no requirements from the commercial sector which require the upper or lower booms. NASA anticipates future commercial interests will wish to use the boom for testing or demonstration of instruments.

The primary projected users of the upper and lower booms are the astronomical, solar-terrestrial, and Earth observational science communities, use is also anticipated by the solar system exploration, life sciences, and communications communities. The deferral of these booms reduces the initial accommodations available to these communities. One attachment point can support one relatively demanding instrument, however, through use of an intermediate instrument carrier, several less demanding instruments can be located at a single attachment point. The two initial attachment points are believed to be in line with the mixture of science instruments which will be available during early Space Station operations.

Question 34: Doesn't the elimination of the dual keel compromise the stability of the Space Station and increase Station keeping requirements that in turn will increase the degree of contamination in the vicinity of the Space Station and reduce the value of the two remaining attachment points?

Answer 34: With the deferral of the dual keel, the thrusters for Station keeping and attitude control will have to fire more frequently to provide the required stability in the planned Station attitude. However, these thrusters have recently been baselined to use hydrogen and oxygen. The resultant effluent is water. As a contaminant, water is a concern to users of infrared wavelengths instruments, which would be the most seriously affected. However, since water is also a contaminate resulting from outgassing of the atmosphere from the habitation and laboratory modules, no extremely sensitive infrared instrument had been planned for direct attachment to the Space Station. Thus the impact of the Hydrogen-oxygen Station keeping system on users will be minimal.

We have been working with the user communities for some time to identify the levels of contamination near the Space Station and the resultant effects on the users. We are continuing this joint activity.

Space Science

The Space Station program was intended to be a significant development for space science both as a servicing facility and a central research center. However, the most recent plan seems to have drastically reduced the scientific value of the station. Whereas materials processing and life sciences are big winners, the other disciplines appear to have lost.

Question 35: Has NASA given any thought to accelerating the schedule for deployment of a Space Station platform in order to manifest its commitment to space science?

Answer 35: The design of the Space Station itself represents a commitment to the many disciplines comprising space science. Our intent is to provide capabilities for both observational and laboratory sciences.

The phasing of Space Station platform availability is driven principally by the schedule of user payloads requiring these platforms. The deferral of a co-orbiting platform, for example, reflects the fact that there simply is no identified near-term payload requiring that platform early on in the program. Should the Office of Space Science and Applications or any other user step forward with a requirement for a co-orbiting platform early in the program, deployment could be accelerated. In principle, deployment of such a platform could precede launch of the manned base.

Space Science

Question 36: The Space Station program was intended to be a significant development for space science both as a servicing facility and a central research center. However, the most recent plan seems to have drastically reduced the scientific value of the Station. Whereas materials processing and life science are big winners, the other disciplines appear to have lost.

Have any discussions along this same line of thought (accelerating the deployment of a Space Station platform in order to manifest the commitment to space science) occurred with our allies who also intend to develop a polar platform, as well as a co-orbiting man-tended facility?

Answer 36: The ESA attached laboratory, polar platform and man-tended free flyer are all elements of the Columbus development program within ESA. ESA has not discussed an earlier deployment of their polar platform, which is scheduled for an Ariane 5 launch in late 1994. The deployment of ESA's man-tended free flyer cannot be accelerated. It is tied to the assembly and operational verification schedule of the manned base, where it must dock for servicing.

Question 37: What is NASA's current thinking about the polar platform? Will it be launched on an ELV (are funds included in the Phase I program for a Titan IV)? Will it be serviceable? When will final decisions be made on these matters and when will NASA commence funding the instruments for the Space Station polar platform?

Answer 37: The official documentation at this time still reflects the original plans, i.e., that the polar platform is to be launched by Shuttle from the Western Test Range. There is, however, planning in progress to reduce dependence on Shuttle and to anticipate the mixed fleet which will be in place in the mid-nineties. Titan IV launch of the polar platform is certainly a part of one potential solution. The question of serviceability is also under study. This decision will depend on the future availability of Shuttle launch capability from the Western Test Range. It is expected that decisions on the availability and capabilities of a mixed fleet, consisting of various types of launch vehicles, will be made within the next year. At that time, Space Station will adapt its planning accordingly.

Definition studies of the polar platform's Earth Observing System are underway. The development phase of the specific instruments to be flown will be initiated after a several year period of advanced development and definition studies. Current planning envisions start of instrument development no later than FY 1991, consistent with a late 1995 launch date.

Question 38: What are the leading candidates for space science attached payloads? Do these instruments require the upper and lower booms?

Answer 38: A number of payloads are planned for deployment on the Space Station, beginning with early assembly flights, continuing through the complete assembly, including the upper and lower booms. The Office of Space Science and Applications has initiated a study to determine the best strategy for deploying these payloads in concert with the Phase 1 and Phase 2 capabilities. A preliminary list of leading candidate experiments which could be performed on the Revised Baseline Configuration, without the upper and lower boom include:

Payload
Plasma Environmental Monitoring System
Laser Communications Engineering Test
Cosmic Ray Nublei Experiment
Hitchhiker ERBE

The following experiments are currently under review to determine if they can be accomplished without the upper and lower booms:

Payload

Solar-Terrestrial Observatory - Solar Instrument Group
Solar-Terrestrial Observatory - Plasma Instrument Group
Cosmic Dust Collection Experiment
Astrometric Telescope Facility
Tropical Rainfall Mapping Mission

Question 39: Without a servicing facility what would be the servicing capabilities of the Space Station? E.g., could the Space Station still service the Hubble Space Telescope and other critical science payloads?

Answer 39: Without a servicing facility the servicing capability of the Space Station approximates that available from the STS cargo bay. Spacecraft could be brought to the Space Station by the OMV. Basic servicing tasks could be performed either by EVA or with the Flight Telerobotic System. The unique capability that the Station will have is its permanent presence.

In the specific case of the Hubble Space Telescope, servicing is required every third year. Because they will take place before the Space Station is available, the first one or more of these servicings has always been planned to be accomplished by the STS. If the provision of the enhanced capabilities does occur relatively soon after completion of the Revised Baseline Configuration, there will be no change in the current plan. If the enhanced capabilities configuration is deferred, additional servicings of the Hubble Space Telescope will continue to be accomplished with the shuttle.

Other critical science payloads will not require servicing until late in the 1990's. As is the case with the Hubble Space Telescope, we will continue to work with the developers to assure that the required servicing can be accomplished either by the Space Station or by the STS.

Question 40: Is the Advanced X-ray Astronomy Facility -- one of the four Great Observatories proposed by NASA -- still a candidate for the Space Station co-orbiting platform or is this payload now considered to be a separate free flyer?

Answer 40: The ultimate decision on AXAF's flight mode will be made after formal mission approval, although current preliminary studies are evaluating several options.

Question 41: Has NASA given any thought to developing an Extended Duration Orbiter or leasing an Industrial Space Facility in order to expand the information base and increase the flight experience prior to deployment of the Space Station elements in order to maximize the scientific return?

Answer 41: NASA's current budget does not include provisions for an extended duration capability for the orbiter. However, we are continuing to analyze the requirements for acquiring extended duration capability. Should an Industrial Space Facility be available NASA would give serious consideration to utilizing its capabilities.

Advanced Technology

One of the more compelling arguments in favor of a U.S. Space Station is that it would advance technology. This in turn would improve the competitive posture of the U.S. in world markets and the technological leadership of the U.S. in space.

Question 42: What are the principal advanced technologies that will be developed for the Space Station and how would they improve our competitive posture?

Answer 42: The Space Station will advance technology in both terrestrial and space applications improving the competitive posture of the U.S. in world markets. The Space Station will contribute substantially to the advancement of the application of several technologies. For example: distributed networks, space processors, materials, structures. Significant spin-offs will also occur from NASA investments in automation and robotics technologies.

In the area of A&R several key technologies will be emphasized: operations/machine interface, sensors and automated perception, task planning and replanning, executive controllers, and automated systems architectures. In the selected areas, NASA is at the leading edge of technological development and expects to make significant contributions to the state-of-the-art. The most important and beneficial application of these contributions may well be in the area of "flexible, intelligent manufacturing."

In addition Space Station will, for the first time, offer American astronauts and scientists permanent manned presence in space. The significance of this permanent presence in space will be in the respective roles of man vs. the spacecraft. Instead of spending the vast majority of time operating under a tight schedule, required by manned "visits" to space, permanently manned capability will allow man to "live" in space and utilize his intuitive and creative abilities. This is man's unique ability and most precious inner resource: unleashing these abilities and resources are the main objectives behind a manned space program. This capability will undoubtedly lead to a variety of serendipitous discoveries; any one of which could significantly enhance our quality of life here on Earth.

Question 43: In light of the fact that solar dynamic power systems and the techniques for assembling structural trusses were important elements of the advanced technology development program why are they being delayed until Phase 2 or terminated?

Answer 43: Solar dynamic technology development is being continued. Its implementation will be considered in the future. It was omitted from the revised baseline configuration as a cost savings measure. The techniques for assembly of structural trusses will be incorporated in the early assembly of the Space Station.

Question 44: Why has NASA been reluctant to promote more advanced technologies for the Space Station -- is it a function of perceived risks or costs -- when clearly it gives added credence and marketability to the program?

Answer 44: Advanced technologies are being incorporated into the Space Station. However, when incorporating advanced technologies into a space system design, the first consideration is safety and reliability and the second pertains to the relationship between development risk and cost. The Space Station program has maintained an advanced development program aimed at lowering development risk and the commensurate cost risk. The program encourages contractors to be innovative and to incorporate advanced technologies in the baseline design. Special efforts will be made to achieve a high degree of technology transparency enabling later incorporation of high payoff technologies, when their maturity is deemed appropriate.

Space Station Transportation

There has been much discussion on Capitol Hill lately concerning the merit of and requirements for a heavy lift launch vehicle (HLLV) -- now referred to as an Advanced Launch System. Recently, Mr. Stofan, you wrote that "in the absence of even a concept, we cannot design a Station that could be launched by a possible HLLV. If we are to have any hope of providing a Space Station by the mid-1990's, we must proceed with a design of the only transportation system that we know will be available, namely the Space Shuttle.

Question 45: Does the NASA Space Station program have any firm requirements for a heavy lift launch vehicle or am advanced launch system?

Answer 45: The baseline strategy for the assembly and logistics support of the Space Station involves only the use of the STS. While the number of Shuttle launches required to assemble the Space Station could be reduced with the use of a launch system with greater lift capability, we do not need such a vehicle to carry out the assembly task.

Question 46: What is the status of the Hook Study on the role of heavy lift launch vehicles in the launch, assembly, and logistical support of a Space Station? When will the Subcommittee be advised as to these findings?

Answer 46: The study is complete. The study included a range of options including some potential benefits for Space Station: the ability to launch fully outfitted modules. If an HLLV or ASL were available, the Space Station could use it for some assembly launches. However, the pre-development status of the HLLV/ALS requires that we plan for the Space Station baseline assembly flights using existing transportation systems. We will be glad to brief the Subcommittee or members of the staff on Mr. Hook's analysis at any time.

Question 47: Didn't Mr. Hook previously assess the use of existing expendable launch vehicles in the launch, assembly and logistical support of the Space Station? What were the principal findings of this report? Isn't NASA currently baselining the launch of the polar platform on an ELV.

Answer 47: The principal findings of the report were that ELV's could possibly be used for some assembly flights and for Polar Platform launches; however, there is increased operational complexity associated with the use of ELV's for assembly flights. With respect to the polar platforms, launch by the STS is still baselined. Launch of the Polar Platform by ELV's is carried as an option. We are continuing to study the utility of the use of ELV's with respect to logistical support.

Question 48: If for any reason, the shuttle fleet were grounded in the future, what contingency plans exist for the use of ELV's and HLLV's to supply or service the Space Station?

Answer 48: The Space Station will be designed to survive without crew on board for extended periods. Additional contingency plans may be developed during Phase C. Analysis of crew emergency return options have been initiated. We recently sent a letter to the Committee indicating our intention to proceed with Phase B studies, and will be releasing the RFP for these definition studies in late summer.

Question 49: What impact, if any, would a decision not to build the fourth orbiter have on the Space Station program? (This portion is currently being discussed as a possible amendment to the Senate Budget Resolution.)

Answer 49: NASA studies indicate that Space Station assembly and logistics are dependent upon a flight rate to the Space Station of 6 to 8 flights per year. Although we are studying a reduction in this level to a rate of five per year, a three-orbiter fleet would have to satisfy the launch requirements of other users. We do not believe that reliance upon the sustained availability of only three orbiters is a wise strategy for a robust space program to pursue.

Question 50: Are we designing this program with sole reliance on the Space Shuttle, a man-rated vehicle?

Answer 50: The Space Station baseline involved the use of the STS for assembly and for crew rotation. Options for logistical support from an ELV, as well as for launch of the polar platform, are under consideration. Crew exchange is dependent upon the STS, since it is the only man-rated vehicle available.

Question 51: Is it possible for a Space Shuttle launched from the Kennedy Space Center to service a polar platform? What about a Hermes (the proposed ESA shuttle) launched from Guinea?

Answer 51: An STS launched from Kennedy Space Center is restricted from flying any inclination higher than 57° for safety reasons. An inclination of higher than 57° brings the Shuttle over densely populated areas. Therefore, although we could physically fly to the Polar Platform from Kennedy, it would violate reasonable safety standards. The Hermes launched from Guinea could reach the polar platform but it is a very inefficient flight path allowing very little payload capacity, limiting its utility in servicing the Polar Platform.

Question 52: Does this mean the proposed Space Station polar platform will not be serviceable?

Answer 52: It may be possible to design the polar platform so that it is serviceable from an ELV. We are going to study the options before making a decision.

Question 53 What role, if any, is expected to be played by foreign or commercial launch systems, with regard to the Space Station?

Answer 53: The role of foreign or commercial launch systems has not been determined. We expect that ESA will use its launch vehicles to service its man-tended free-flyer. Partners may use their launch systems for resupply and transportation activities if those systems are technically compatible with Space Station interfaces. Responsibility, financially and technically for compatibility, will lie with the partners.

Extended Duration Orbiter/Industrial Space Facility

Based on the testimony before the Subcommittee today, a consensus seems to be emerging that certain "interim steps" are required if the Space Station's potential is to fully be utilized. Included on this list are increased Spacelab flights, development of an Extended Duration Orbiter (would increase shuttle's flight duration from 7-10 days to 14-21 days) and an Industrial Space Facility or man-tended facility that could be available in the 1991-92 time frame.

Question 54: Could you please advise the Subcommittee as to the status of each of these initiatives? What benefits and opportunities do each of these options present?

Answer 54:

(a) From the Space Station program perspective, Spacelab flights would be valuable to develop precursor experiments and instruments for Space Station payloads, in addition to the pure scientific return of such missions.

(b) While we have no firm requirements for an Extended Duration Orbiter, the Program is studying ways in which one might be useful.

(c) The Space Station Program is currently negotiating a Phase C/D MOU with Space Industries Partnership which builds upon our present Phase B MOU. The purpose of the Phase C/D MOU with Space Industries is to continue the exchange of information to ensure the operational compatibility of the Space Station and Space Industries' Industrial Space Facility (ISF) and to develop the necessary information for additional agreements addressing the potential use of the ISF in support of Space Station development. As part of these negotiations, the Office of Space Station is evaluating the ISF as a commercial entity, in association with the Space Station and Space Industries as a commercial participant in the Program.

It is conceivable that the ISF could be beneficial to the Space Station development program in the form of a space-based testbed for Space Station technologies. The Phase C/D MOU will specifically address this issue.

According to Space Industries, the ISF could provide opportunities to the user communities to prepare themselves for Space Station. However, the Office of Space Station is not addressing whether the ISF could serve as an interim step for the user communities prior to the Space Station era.

Question 55: What is the estimated cost of an Extended Duration Orbiter, and which shuttle is the best candidate for configuration for extended flight time?

Answer 55: An Extended Duration Orbiter with a flight duration increased to 16 days would use a pallet of four cryogenic tank sets in addition to the four tank sets normally carried. The estimated cost is in the range of $90 million - $115 million (FY 1987 dollars) depending upon the extent of orbiter modifications and added provisions for crew support. An extension to approximately 20 days requires a solar cell array power extension package that has been estimated to cost about $225 million (FY 1987 dollars).

The existing Orbiter fleet has a baseline capability of 7 days in orbit. Columbia, OV-102, has provisions for a fifth cryo tank set that provides the potential for a 10-day staytime. Because of OV-102 payload weight constraints, OV-103, OV-104, and OV-105 are preferred candidates to be configured for extended duration. The best single vehicle candidate would be OV-105, because modifications could be made in the build cycle at Palmdale without impacting the ground flow processing schedule at KSC, as would be the case for OV-103 and OV-104.

Question 56: What is the current status of NASA's discussions with Space Industries, Inc. as to the value of an Industrial Space Facility to the civil space program? If NASA wanted to enter into a "service agreement" with Space Industries, does it have the legal authority?

Answer 56: The Space Station Program is currently negotiating a Phase C/D MOU with Space Industries Partnership which builds upon our present Phase B MOU. The purpose of the Phase C/D MOU with Space Industries is to continue the exchange of information to ensure the operational compatibility of the Space Station and Space Industries' Industrial Space Facility (ISF) and to develop the necessary information for additional agreements addressing the potential use of the ISF in support of Space Station development.

As part of these negotiations, the Office of Space Station is evaluating the ISF as a commercial entity in association with the Space Station and Space Industries as a commercial participant in the program.

Space Station's discussions with Space Industries are focused on technology compatibility between the two systems and the possible use of the ISF in support of Space Station development. It is conceivable that the ISF could be beneficial to the Space Station development program in the form of a space-based testbed for Space Station technologies. The Phase C/D MOU will specifically address this issue. The Office of Space Station is not addressing whether the ISF could serve as an interim step for the user communities prior to the Space Station era.

Servicing

One of the original rationales for the Space Station is that it could serve as an on-orbit servicing facility for satellites. For example, it would be the place where operations such as refueling satellites, changing worn out components, adjustments, etc. could be done. The Space Telescope was designed, in part, to take advantage of this capability for the Station, since that will need very delicate adjustments and servicing on a periodic basic. To service satellites, one must protect against direct sunlight and against space-borne contamination, especially from the thruster rockets on the space suits or the shuttle.

The servicing center could be thought of as a combination garage and work area for the crew of the Station. Satellites could be stored there to be worked on by the crew. The crew would not have to worry about lighting or about floating away, which would increase productivity. Finally, it would serve as a garage for the OMV, which is the "space tug." Now, the servicing center is going to be deferred until the second phase of the Space Station program.

Question 57: Is servicing still a priority on the phased design? If so, what types of servicing do you envision will be possible, and where will this servicing occur?

Answer 57: Because of the fiscal constraints through FY 1990, the Phase I program does not include the upper and lower boom, three additional payload attach points, and the servicing bay. This is consistent with planned near-term requirements for servicing. However, there is limited servicing capability which meets all of the basic servicing requirements for the early Phase of the Program. The Flight Telerobotic Servicer provides an initial servicing capability. NASA intends to develop a fully capable servicing system as the Space Station's capabilities are enhanced and the specific assets requiring this kind of servicing are developed and placed in orbit.

Question 58: Is there any specific funding for servicing in Block I? Isn't it possible to add some servicing capability in the first phase? How much would it cost to put the full servicing capability into Block I, and is it feasible in terms of added mass and weight to the Station?

Answer 58: In FY 1988 dollars, the servicing facility was estimated to cost approximately $477 million. There is limited servicing capability consistent with Phase I requirements for attached payloads. The phased approach calls for the first stage of this capability, the Flight Telerobotic Servicer, to be included in the first element launch. The Canadian supplied part of the mobile servicing system (MSS) would be completed at launches 3 and 4, allowing servicing of attached payloads and limited station maintenance. Phase II capabilities could include the addition of the mobile base to the MSS. Full servicing capability is not required until later when the various spacecraft requiring servicing are in place. Due to the Challengers accident the development and launch of many of these spacecraft have been delayed.

Question 59: Is it possible to phase the servicing capability to give the Station some capability in Block I? Isn't that capability going to be required for satellite servicing and for on-orbit repairs to Station-related modules? Couldn't this servicing capability be phased along with the Station so that it could grow into the full system at a later date? What would it cost to do it in this way?

Answer 59: It would be possible to phase in the Servicing Facility with initial capabilities provided in the Revised Baseline Configuration. However, initial servicing requirements are limited and will be accommodated with the capabilities of the Phase I configuration. NASA contractor's are studying the potential cost of a phased approach to full-up servicing.

Operations

Question 60: Could you inform the Committee when it will receive a briefing on the current Space Station operations plan? Is that plan complete at this point, and has it been approved by the Administrator?

Answer 60: The Office of Space Station established an Operations Task Force to develop recommendations for an operations plan. The Operations Task Force has completed its work and has reviewed its conclusions with NASA management and with the Oversight Committee which was established to provide a critical review of those conclusions. The Administrator reviewed the recommendations on May 15, 1987. House and Senate staff were briefed on the Task Force results on June 1 and 2.

Question 61: Regarding operations, the Space Station assembly will require multiple docking maneuvers, correct? Have we ever docked the Space Shuttle; do we even know how to dock one? The airlock on the Shuttle is in the payload bay, so docking may be more difficult than with the Apollo and Gemini systems, which were essentially docked head on. Is contamination of the payload bay a potential problem in docking maneuvers?

Answer 61: The Space Station will be assembled to the greatest extent possible by use of the Remote Manipulator System (RMS) in the Orbiter and later by the Mobile Servicing Center (MSC) on the

Station. A berthing technique will be used in which either the RMS or the MSC will grapple the component being added to the structure and place it in the assembly. This technique will be used to berth and dock the Orbiter to the Station itself. Although this approach calls for delicate proximity operations, the inherent difficulties associated with docking are minimized. This technique has been successfully employed in the recover of the WESTAR and the PALAPA satellites and the repair of the Solar Maximum Spacecraft. We recognize the difficulties of berthing and docking the orbiter to the Station. Studies will be conducted at the Johnson Space Center in the Automated Assembly and Integration Facility, an FY 1989 Construction of Facilities project request, to determine the best ways of dealing with the problems.

With regard to potential contamination of the payload bay during berthing, we feel that this risk is minimal due to the relatively clean atmosphere in the vicinity of the Station achieved by the use of the hydrogen/oxygen propulsion system on the Station.

Question 62: Isn't it correct that the Apollo and Gemini programs practiced extensively docking and undocking, using a sort of "dummy" system. Are any of the flights on the shuttle manifest between 1988 and 1994, when construction begins, specifically planned now for docking maneuvers? What system is now being contemplated for use as the "dummy" system in order to practice the maneuvers? Has NASA begun design work on that system; are any funds requested for that purpose?

Answer 62: Flight tests of on orbit operations techniques, including berthing and docking, will be scheduled as needed to validate the design of Station hardware. Examples of such technology demonstrations previously conducted in space include the Experimental Assembly of Structures in EVA/Assembly Concept for Construction of Erectable Space Structures (EASE/ACCESS) and the Solar Array Flight Experiment (SAFE). Flight tests supporting the development of the Flight Telerobotic Servicer (FTS) as well as for understanding techniques for the control of flexible structures (COFS) in space have been funded.

NASA
National Aeronautics and
Space Administration
Washington, D.C.
20546

Reply to Attn of: XC:MDD:C-21655f

SEP 28 [illegible]

Honorable Larry Pressler
Ranking Minority Member
Subcommittee on Science, Technology
and Space
Committee on Commerce, Science
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Pressler:

Enclosed are the final responses to written questions resulting from the April 29, 1987, hearing at which Mr. Myers and Mr. Stofan testified on NASA's FY 1988 Space Station budget request.

Sincerely,

John J. Madison
Acting, Chief
Congressional Liaison Branch

Enclosure

cc:
Mr. Pete Perkins

Responses to written questions submitted by Senator Pressler.

Revised Baseline Plan

Question 1: Why was the previous Space Station baseline plan "revised" -- what was inherently "wrong" with the previous baseline that warranted the 2 to 3 month pause in the program while the Administration reviewed the Program?

Answer 1: The previous Space Station baseline configuration was revised in view of NASA's new cost estimates. Technically, and from the point of view of the user communities, there was nothing "wrong" with this configuration. The Revised Baseline Configuration effectively balances fiscal restraint and necessary capabilities for a permanently manned Space Station.

Question 2: What features in the revised baseline plan compensate for the additional costs of the revised baseline plan, the additional time to achieve the final capability, and the "gap" in capabilities that will occur while Block II is being developed and deployed?

Answer 2: The phased approach to Space Station development was adopted as a means to meet budgetary requirements. The scheduled changes primarily resulted from our assessments of the overall program schedules for the CETF configuration and an additional six months delay due to budgetary constraints. The pace and scope of realizing Space Station capabilities beyond the Revised Baseline Configuration have not yet been determined.

Question 3: What is your understanding of what will be required to initiate Block II in FY 1991 -- will this require a separate Congressional approval as if Block II were an altogether new and different program? If so, do you not believe that this imposes political risks on the program that might not otherwise occur under the previous baseline program?

Answer 3: Developing Space Station capabilities beyond the Revised Baseline Configuration will require approval of both the Executive Branch and the Congress given the policy implications of such evolution as well as the budgetary requirements.

Programmatic Costs

Question 4: Space Station development requirements in the FY 1987 and FY 1988 budgets are, respectively, $150 million and $733 million. With the delays that have been imposed on, or built into, the program over the past few months, will NASA require all of these development funds in FYs 1987 and 1988, or, put another way, have some of these budget requirements been "pushed to the right" in keeping with the new delays in the program?

Answer 4: The Space Station Program should have the full $150 million and $767 million funding for the FY 1987 and FY 1988 development program. The development budget and the cumulative funding through FY 1988 is needed to support the first element launch in March 1994 and the man-tended date of March 1995.

Question 5: What are the total programmatic costs for Block I and Block II, in 1988 dollars, and how does this compare to the costs associated with the previous baseline?

Answer 5: The Office of Space Station costs associated with the current Block I/Block II configuration as well as with the previous enhanced configuration are provided in the following table.

Reconciliation of Space
Station Baselines
(Billions of Dollars)

	Enhanced Configuration (FY 88$)	Current Baseline (FY 88$)
Block I		
Flight Hardware Development	15.4	13.0
Flight Telerobotic System	0.3	0.3
Basic Lab & Test Support	1.6	1.6
Transition Definition	0.2	0.2
Operations (through FY 96)	3.8	3.4
Block II		
Flight Hardware Development	(incl above)	4.0
Basic Lab and Test Support	(incl above)	0.5
Total	21.3	23.0

The previous baseline assumed a full-up development program including a co-orbiting platform, 50 kW of photovoltaic power and 25 kW of solar dynamic power, and a First Element launch in January of 1994.

The revised baseline includes 75 kW of photovoltaic power, [illegible] co-orbiting platform, and a First Element Launch in first quarter of 1994.

Question 6: Would you please verify for me the following costs associated with Space Station development through FY 1996 and indicate if these costs are contained in the development costs of the program -- the Flight Telerobotic System ($290 million); Transition definition costs ($230 million); and Operations costs ($3.44 billion)?

What are the transportation costs, both Shuttle and ELV, associated with carrying the program through the deployment of all of the Block I infrastructure? Likewise, what are the transportation costs for the deployment of all of the Block II infrastructure?

Answer 6: The current estimates of $292 million for the Flight Telerobotics System, $230 million for the Transition Definition and $3.4 billion for Operations through FY 1996, are correct. These estimates are expressed in 1988 constant dollars. The development program estimate for Phase I is $14.5 billion and does not include the Flight Telerobotics System, Transition Definition or Operations costs, which are being budgeted separately.

The marginal transportation costs for the Space Shuttle for launching the Revised Baseline program are estimated at $0.8 billion in constant 1988 dollars. This estimate covers the 19 Shuttle launches required. If the second phase of the Space Station is implemented with the same content as envisioned prior to the decision to proceed with the revised baseline, an additional 12 Shuttle launches would be required. The marginal cost, in constant 1988 dollars, of these launches would be approximately $0.5 billion.

Question 7: What are the peak funding years of the Space Station program and their associated budget requirements, particularly in those years in which budget requirements for Block I and Block II would co-exist?

Answer 7: The peak funding years for the Space Station Revised Baseline Program Development Activities are FY 1992 and FY 1993. The Phase II funding projections shown below assume authority to proceed in FY 1991 and extend into FY 1997 and FY 1998. The current estimates of the associated budget requirement for those years are listed below. All estimates are stated in FY 1988 constant dollars in billions, and include the Flight Telerobotic System (FTS), Transition Definition, and Operations. These estimates do not include construction of facilities, research and program management or Space Transportation Systems and Tracking and Data Network support costs.

	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996
Block I	2.6	2.9	2.7	1.9	1.4
Block II	.1	.6	.9	.9	.8
	2.7	3.5	3.6	2.8	2.2

Question 8: A February letter from OMB Deputy Director Joe Wright to Dr. Fletcher describes NASA's annual budget through FY 1992 to be approximately $11 billion.

To what extent will NASA be able to accommodate within annual budgets of $11 billion its Space Station related costs, the costs of its ongoing programs, and the costs of initiating new programs that are unrelated to the Space Station program?

Answer 8: The FY 1988 budget guidance given to NASA by OMB covers the projected runout of the programs included in the President's Budget recommendations. New programs which may be proposed in the future or significant changes to on-going programs are generally not anticipated in this runout of the President's budget for NASA.

Question 9: What are the major drivers in the operations costs, and are we to assume that the total operations costs of $3.44 billion in operations costs through FY 1996 are all to be borne by NASA?

How will the operations costs of the international participants be determined, and, if NASA is expected to absorb $3.44 billion in operations costs through FY 1996, what are the estimated operations costs for the international participants during this same period?

Answer 9: The operations budget through FY 1996 funds the preparation for operations during the assembly phase and on into mature operations. Key drivers include flight hardware spares, prelaunch processing of flight hardware at the launch site, crew training, and operations of ground-based support systems. These costs are estimated on the nature of the flight hardware defined in NASA's Space Station development program, and will be be borne by NASA.

NASA's position with respect to its partners is that each one will bear the cost of operations during this period associated with the flight hardware and crew members it provides. Thus, ESA, Japan, and Canada will each fund the acquisition of spares and prelaunch processing for their flight hardware, the training of crew members they supply, and the operation of the ground-based support systems they build.

At the present time, NASA is involved in various working group activities with its partners to develop better mutual understandings regarding potential future operational costs for the Station. Although many details are not yet available from the partners, NASA expects it would be roughly comparable to U.S. costs for like hardware elements.

Question 10: It is my understanding that through FY 1996, NASA will expend approximately $225 million on major facilities projects? What will be the nature of these projects, and where will they be located?

Answer 10: Many requirements for the Space Station will be satisfied by the use of existing NASA facilities. However, requirements for the construction of new facilities or the modification of existing facilities have been identified in the areas of power, propulsion, and communications systems development; human performance; launch site processing; mission control operations, training, and logistics. Facilities for the development of electrical power systems are planned for the Lewis Research Center; for propulsion systems at the Marshall space Flight Center; for systems engineering, integration, and assembly at the Johnson space Center (JSC); for prelaunch and post landing processing and logistics at the Kennedy space Center; and for mission operations, training, and simulations at the JSC.

Space Station Power

Question 11: I understand that the initial studies of Space Station power requirement indicated that a hybrid approach consisting of photovoltaic and solar dynamic power would provide the most efficient power system, based on the higher life cycle costs associated with a purely photovoltaic system.

Can you explain to the Subcommittee what has changed so that now you are considering using only 75 kW of photovoltaic power in Block I?

Answer 11: The cost constraints imposed on the Space Station budget do not allow for the full design and development of both the photovoltaic and the solar dynamic power modules in Block 1. In addition, estimated life cycle costs originally associated with the use of extensive photovoltaic arrays have been reduced by our decision to use a hydrogen fueled propulsion system.

Question 12: What is the estimated difference in the initial costs of providing 50 kW of photovoltaic power and 50 kW of solar dynamic power? Similarly, what is the estimated difference in life cycle costs for the same two power systems?

Answer 12: The cost trade-offs between the photovoltaic arrays power system and a hybrid system including solar dynamic power generation are complex. The higher cost of developing the solar dynamic system is offset by lower operations and maintenance costs, longer life and increased potential for future expansion. The photovoltaic arrays development is estimated to cost $250 million. The development of a hybrid system with 50 kW from photovoltaic and 25 kW from solar dynamic systems would cost $400 to $500 million.

Photovoltaic array systems have been used extensively in space and a large amount of data exists on their performance and costs. Nonetheless, significant technical challenges remain. The enormous size, manufacturing difficulties and orbital performance characteristics make its development and operation not without risk.

On the other hand, solar dynamic systems have been evaluated in only ground-based engineering tests and have a higher degree of development and operational risk. The major advantage of these new systems is the relative efficiency in power production and relatively high reliability. Lower annual operating costs per kilowatt of power are anticipated with mature solar dynamic systems.

(NOTE FOR Question 13: "Scarring" is a term of art that refers to the design and development of a component or system so that it will accommodate future changes.)

Question 13: If Block I will not have solar dynamic power, will the Space Station be "scarred" to accept solar dynamic power in Block II?

Answer 13: Yes, the Space Station will be scarred to accept additional power modules. They could be either solar dynamic modules or additional photovoltaic modules.

Question 14: As you know them now, what are the specific nature and magnitude of the "housekeeping" power requirements for the Space Station in Block I?

Similarly, what are the specific power requirements for the operation of each of the laboratory modules to be supplied by the U.S., ESA, and Japan, and what specific activities and functions will drive these requirements?

Answer 14: Housekeeping power requirements in Block 1 are at this time estimated as follows:

Environmental Control and Life Support System	13.3 kW
Data Management System	5.9 kW
Communications and Tracking	3.3 kW
Thermal Control System	2.8 kW

Guidance, Navigation & Control	1.6 kW
Fluid Systems	1.4 kW
Propulsion	1.1 kW
Manned Systems	0.9 kW
Mechanisms	0.6 kW
Extra Vehicular Activities	0.1 kW
Mobile Servicing Centre	0.3 kW
Other	0.7 kW

Although our preliminary estimates for housekeeping requirements indicate a level slightly above 30 kW, we are targeting a ceiling of 30 kW for general housekeeping. NASA's experience in time phasing of electrical systems aboard the Shuttle confirm that this is a fully achievable goal. Preliminary housekeeping estimates for the Shuttle ran between 16-18 kW. The current housekeeping requirements on the Shuttle are about 11 kW. Space Station Program Definition Requirements Documents (PDRD) indicated preliminary estimates of 36.8 kW. This has now been reduced to slightly more than 30 kW. Given further engineering, design work and effective power management there should be no difficulty in meeting the goal of 30 kW.

Question 15. With a power supply of 75 kW in Block I, rather than 87.5 kW as in the previous baseline, to what extent will space science in the pressurized modules suffer?

Answer 15: Space Station user power under the revised baseline configuration will be approximately 45 kW. This level of power should be sufficient to meet the power requirements of all Block I user requirements both within the labs and for a variety of attached payloads.

Question 16: According to the statement of Mr. Stofan, ESA is expected to supply a man-tended free flying platform. When is this platform likely to be deployed, and would its power usage be in addition to ESA's power allocation, or would it come from within ESA's power allocation?

Answer 16: We agreed with ESA that the Man-Tended Free-Flyer (MTFF) can be serviced by the Space Station after the completion and operational verification of the manned base. MTFF could be launched up to 6 months prior to this. All resources required for MTFF servicing, including power, would come from ESA's current allocation to its laboratory.

Question 17: Are you confident that your power level of 75 kW in Block I will satisfy all housekeeping and operational requirements and still provide a margin that will support additional operational activities not yet defined?

Answer 17: Our analyses show that 75 kW is adequate to cover both housekeeping and user requirements as they are defined at present for Block I. We do, however, expect the demand for power to increase once the Space Station becomes operational. We are therefore "scarring" the power management and distribution system to 175 kW, as well as continuing the technology development of the solar dynamic system. This will enable us to increase power as the need arises.

Space Station Servicing

Question 18: According to the statement of Mr. Stofan, the Flight Telerobotic System is retained in Block I, yet, the U.S. supplied servicing bay will be deferred to Block II.

What are the implications of deferring this servicing bay?

Answer 18: No major FTS problems are caused by not having the servicing facility on the Block 1 Station. The hangar is not required for environmental protection of the FTS. Other options for storage, and possibly of on-orbit repair, will be studied during the FTS Phase B and integrated into the Space Station Phase C design. In addition, the projected mission model requirements that indicated the need for early availability of a servicing bay capability have now been updated. The updated plans do not indicate a pressing requirement for early availability of the servicing bay that would warrant a commitment now to its implementation.

Question 19: Without a servicing bay in Block I, what Space Station accommodation will there be for the Orbital Maneuvering Vehicle (OMV) during Block I?

Answer 19: The OMV does not have to be housed in the servicing bay. On the Critical Evaluation Task Force (CETF) Space Station configuration, the OMV accommodations were minimal--essentially a parking place on the structure plus some power and data transmission lines. However, the hydrazine refueling system of the servicing facility could have been used to refuel the hydrazine portion of the OMV (the "Short Range Vehicle"). Currently, no OMV accommodations are planned for Block 1 of the Space Station, but the matter is still under consideration. Since the accommodation requirements are minimal, it would be relatively easy to add these accommodations at any time.

Question 20: It would appear that without the servicing bay to "hangar" the OMV, this would reduce significantly the role that the OMV could play in Block I. Furthermore, the absence of the servicing bay would appear to require the delivery of the OMV by the Shuttle each time there was a need for the OMV within the proximity of the Space Station. This, in turn, would decrease the payload capacity of the Shuttle, if the Shuttle is required to ferry the OMV to the Space Station each time it is needed.

Could you comment on the interrelationship of the servicing bay, the availability and role of the OMV, and the payload capacity of the Shuttle?

Answer 20: The absence of the servicing hangar does not preclude the use of the OMV. The OMV does not require a hangar. The requirement to bring the OMV up on the Shuttle does decrease the Shuttle payload capacity. However, this capacity decrease is only equal to the dry weight of the OMV, approximately 6,000 - 7,000 pounds. The fuel for the OMV must be brought up on the Shuttle whether or not the OMV is space-based. Approximately two-thirds of the total weight of an OMV is fuel.

The possibilities for use of the OMV at the Space Station are:

(1) transport it on the Shuttle for each use; (2) transport it to the Space Station on the Shuttle and leave it "parked" there for a series of uses, but return to ground for maintenance and refueling; (3) permanently base the OMV at the Space Station for maintenance and hydrazine refueling. The bi-propellant portion of the OMV must be resupplied by replacing the propulsion module; this weighs about 11,000 pounds and must be transported on the Shuttle. A hangar is not required, although it might be used if available.

Case 1 is the current plan for Block 1 of the Space Station. Case 2 was the CETF plan, with the modification that hydrazine refueling at the servicing facility would have been available if the hydrazine portion of the OMV (the "Short Range Vehicle") required refueling on-orbit. Case 3 was not a part of the CETF plan and is not currently planned for Block I but is an option for the Space Station evolution phase.

Question 21: How will the absence of the servicing bay during Block I affect the ability of the OMV to conduct its servicing requirements, such as for the Hubble Space Telescope and the Gamma Ray Observatory?

Answer 21: Satellites, such as the Hubble Space Telescope and Gamma Ray Observatory, can still be serviced from the Shuttle. The Shuttle-based OMV will retrieve the satellite to the Shuttle orbit and reboost it to the operational orbit after servicing.

Question 22: How and to what extent will the capabilities and use of the Flight Telerobotic System be compromised by the absence of the servicing bay during Block I?

Answer 22: The lack of the Servicing Facility on the Block I configuration will not impair the capabilities of the FTS. It is envisioned that most of the early FTS activity will not require extensive environmental protection. The storage and potential repair accommodations, originally to be provided by the servicing facility, will have to be relocated. Options to accomplish this will be studied during the FTS Phase B and will be integrated into the Space Station Phase C design.

Question 23: What Canadian-supplied servicing capabilities and hardware will be retained in Block I, and which will be deferred to Block 2?

Answer 23: Most of the Canadian MSS hardware will be included in Block I. Delayed until Block II is the bulk of the MSS Maintenance Depot and a U.S. supplied transporter with enhanced mobility capability for the MSC.

Question 24: Based on the U.S.-supplied servicing capabilities that will be deferred to Block 2 and those of Canada that will be deferred, which participant -- the U.S. or Canada -- will have the lead in servicing capabilities in Block 1?

Answer 24: There has been no change in the functional roles of the U.S. and Canadian hardware vis a vis servicing. Hardware supplied by both the U.S. and Canada will be necessary to perform the servicing functions in the Block I configuration. The U.S. is providing the Flight Telerobotic Servicer on the first assembly flight of Block I.

Question 25: With the deferral to Block II of the upper and lower booms of the Space Station framework, I understand that the number of attachment points for space science payloads is reduced from 5 to 2.

What disciplines of space science are affected by this deferral, and what is being done, otherwise, in Block I to compensate them?

Answer 25: All 5 of the attachment points were originally located on the upper and lower booms, 3 on the upper boom and 2 on the lower. The movement of 2 attachment points to the cross truss included in Phase 1 (Block I) is a significant effort to accommodate the space science users.

A Space Station-provided pointing system has also been retained in Phase 1 to support users of these attachment points.

The affected science disciplines are astronomy, solar-terrestrial physics, and Earth observations. Any of the three can be accommodated on the attachment points provided in Phase 1. The pointing system will probably be used to support an astronomy instrument.

The Earth observations community has been particularly interested in the early availability of the polar platform, which was retained in Block I for that reason.

Question 26: According to the statement of Mr. Stofan, Block II "might well include an unmanned free-flying co-orbiting platform." This use of the phrase "might well include" seems to indicate a lessening of support for the co-orbiting platform, beyond the fact that it is not retained in Block I.

Could you comment on the anticipated role of the co-orbiting platform, as well as the likelihood that the Advanced X-ray Astrophysics Facility will use this platform?

Also, what other specific facilities and payloads are likely to use the co-orbiting platform?

Answer 26: A decision as to whether a co-orbiting platform will be included in Phase 2 (Block II), will be based on user requirements. The NASA Space Station-provided platform is modular in design. During the design of the polar platform for Phase 1, the modules will also be designed to support a co-orbiting platform. The provision of a co-orbiting platform in Phase 2 would thus be simplified, requiring only the procurement of additional modules and design of a mounting structure suitable for the intended usage.

At the present time the co-orbiting platform is envisioned as a supporting platform for major science instruments such as the Advanced X-ray Astrophysics Facility (AXAF) if it becomes an approved mission. It will be determined whether AXAF will remain a candidate user of the co-orbiting platform or whether the AXAF program will provide its own spacecraft as part of the preliminary definition studies.

Other potential users of a co-orbiting platform are the Space Infrared Telescope Facility (SIRTF), if approved, and instrumentation supporting the solar-terrestrial physics science community.

(NOTE TO Question 27: The polar-orbiting platform in the Space Station Program requires a launch from the west coast (Vandenberg Air Force Base). The design of this platform assumes that it can be serviced by man from the Shuttle; however, this will require the availability of the shuttle launch complex at Vandenberg, which is, for intents and purposes, being mothballed until at least 1992. Whether this west coast shuttle launch complex will ever be activated is doubtful.)

Question 27: As for the Polar-orbiting platform in Block I, what are your current plans for a launch vehicle, given the "minimum caretaker" status of the shuttle launch complex at Vandenberg?

If the shuttle launch complex at Vandenberg is never activated and, consequently, the polar platform cannot be serviced by the shuttle, how will this affect the design, the life and the capabilities of this platform?

Is there a possibility that it could be serviced by the Orbital Maneuvering Vehicle (OMV)?

Answer 27: We are currently analyzing the potential of launching the polar-orbiting platform with the TITAN 4 expendable launch vehicle. We are still assuming that the Shuttle launch complex at Vandenberg will be activated in time to service the polar platform during the late 1990's.

The OMV might be able to service the polar platform if the state of the art of automation and robotics reaches the capability level that we anticipate by the year 2000. The concept is under intensive study by the Work Package 3 contractor, GE/RCA.

Question 28: According to the testimony of Dr. Banks of the Task Force on the Scientific Uses of the Space Station, the design of the Polar-orbiting platform is lagging behind that of the core Space Station. Is this, in fact, true? If so, please explain why this "lag" has occurred, the extent of this "lag", and what can be done to get the design of the polar platform back on schedule?

Answer 28: The polar-orbiting platform will be configured with building blocks that have a heritage to the core Space Station manned base. Some of these building blocks have achieved a higher degree of definition than others. On balance, the state of definition of the polar-orbiting platform is equal to the core Space Station.

The current staytime in orbit for an orbiter is 7 to 9 days. Because staytime limits the scope of some space science experiments, some space scientists have supported the modification of one of the current orbiters to increase its in-orbit staytime to 14 to 20 days. This additional orbit time would enable space scientists to achieve more meaningful data from their experiments, but could cost $100 million to $200 million and could affect the Shuttle's lift performance and schedule.

Question 29: In the testimony to follow of Dr. Banks, the Task Force on Scientific Uses of the Space Station recommends the use of an extended duration orbiter (EDO) to enhance space research capability prior to the availability of the Space Station. For the past 3 to 4 years, NASA has studied the use of an extended duration orbiter, only to conclude that the costs outweigh the benefits.

Are circumstances different enough now to seriously consider the development of extended duration orbiter? If so, what are the likely costs associated with this effort and how would it affect the Shuttle manifest?

What would be the effect on Shuttle lift performance in extending the in-orbit staytime on an orbiter, and what other considerations should be taken into account in determining whether to develop an extended duration orbiter?

Answer 29: Response to be provided by mid-October.

Space Transportation

Question 30: What is the current thinking concerning the use of a heavy-lift launch vehicle (HLV) for Space Station assembly?

What about the use of an HLV for the deployment of Block II infrastructure?

When would a decision concerning the development of an HLV have to be made in order to support the deployment and assembly of Block I infrastructure?

Similarly, when would such a decision have to be made if the HLV were available only to support Block II?

Answer 30: Our baseline concept envisions the assembly of the Space Station by the Shuttle through achievement of a permanently manned capability. We are intensively examining the viability and effectiveness of completing Space Station assembly and logistical support for the Space Station by a mixed fleet, which could include an HLV.

While the initial assembly must be predicated upon a currently available launch system, the Space Shuttle, we are examining how to productively use a heavy-lift vehicle, if such a vehicle becomes available during the assembly process. One potential scenario, which would not alter the current design, would be to take advantage of a heavy-lift vehicle's payload performance capability by outfitting the pressurized modules on the ground prior to launch rather than in orbit.

Question 31: How many shuttle-equivalent flights are assumed for the deployment and assembly of Block I infrastructure, and how many shuttle-equivalent flights would be required for Block II? How many annual shuttle-equivalent flights are assumed for Space Station resupply and logistics?

Assuming a four-orbiter fleet and an annual shuttle flight rate of 12 to 15 flights per year, do you have any doubts as to the availability of the shuttle system for the Space Station program?

Answer 31: As currently envisioned, the Block 1 infrastructure would require 19 Shuttle flights for deployment: five in the first year, six in the second, and eight in the third. One of these flights is for the U.S. polar platform and may be transitioned to a TITAN 4. In addition to these 19 flights, the ESA polar platform will be launched by an Ariane.

Twelve additional flights would be required for the provision of the enhanced capabilities. In terms of Space Station resupply and logistics the current baseline calls for eight flights a year. However, the program is committed to reducing this requirement to a target of five flights per year and have studies on-going to find ways to achieve this efficiency.

Question 32: Has ESA stated its desire to use its Ariane ELVs or its Hermes spaceplane for any of its own missions to the U.S. Space Station? If so, in what ways?

Does NASA have any concerns about ESA's use of Ariane or Hermes for Space Station missions? If so, what are these concerns?

Answer 32: In March 1984, when then Administrator Beggs visited the summit nation capitols to extend the President's invitation to cooperate in the Space Station, Europe stated it wanted to use its European Space Transportation System in connection with the Space Station. Beggs agreed that such use was appropriate in the context of European cooperation in the Space Station, provided that Europe was responsible for making its transportation system compatible with the Station. Since that time, NASA and ESA have exchanged the information necessary for ESA to accomplish that.

Crew Escape Rescue Vehicle

Question 33: What is the current thinking on the development of a Space Station emergency crew escape rescue vehicle?

What are the major considerations in designing and developing such a capability?

How many crew members would such a capability transport, and what is a range of costs that would be required to develop this capability?

Answer 33: We plan to initiate a detailed requirements and systems definition of a potential alternative crew return capability. In FY 1987, the definition activity will consist of an in-house effort followed by two or more contracts with industry. As requirements have not been defined at this time, a discussion of the design and development considerations is premature.

International Negotiations

Question 34: I understand that the Department of Defense is no longer insisting that the intergovernmental Space Station agreements contain language permitting use of the Space Station for "national security" purposes. Has DOD yet clarified its potential use of the Space Station?

Answer 34: The Administration continues to maintain the position that an explicit reference to the U.S. ability to use the Space Station for "National Security" purposes be contained in an Agreed Minute attached to the intergovernmental agreement. However, DOD has not identified any requirements for the Space Station, but the U.S. will keep the option open for use should such use materialize.

Question 35: Furthermore, I understand that the U.S. has chosen to narrow its veto authority over how ESA and Japan might use their respective modules, by no longer insisting on the veto authority for reasons of national security or foreign policy. Yet, as I understand, the NASA draft agreement still retains NASA's veto authority over programmatic and operations issues, such as public safety, even though the international partners strongly oppose this authority. To what extent is this veto authority negotiable, or will NASA insist on this particular veto authority?

Answer 35: The details of the Station management are still being negotiated with the partners in the international agreements. The U.S., as majority partner, will retain sufficient control to ensure safe, efficient and effective development and operation of the Station. At the same time, the partners will play a very important role in the management of the Space Station through their participation in the various groups responsible for different aspects of Station development, operation and utilization. NASA has no intention of exercising its management prerogatives in disregard of the partners' interests, but will not compromise on those management principles which it finds necessary to ensure safety, orderly program development and reliable Station at all times.

Congressional Funding Commitment

Question 36: The agreement reached by the Administration concerning the Space Station program calls for legislation for a rolling three-year Congressional commitment.

To what extent would a three-year Congressional commitment restrict the funding required for FYs 1989 and 1990, and what affect would this three-year commitment have on Space Station total development costs and schedule?

Answer 36: To the extent the 3-year commitment includes the funding necessary to meet our anticipated funding requirements for any given 3-year period, the Space Station development is expected to proceed on schedule. If the rolling 3-year commitment falls below our anticipated needs, then the impact on the Space Station development cost and schedule would have to be reviewed in light of the magnitude of the budget reductions that the commitment would impose on the Program's activities.

Operations Task Force Study

Question 37: Mr. Stofan, I understand that the Space Station

Operations Task Force has, by and large, completed its study on Space Station operations.

What are the conclusions and recommendations, albeit preliminary, of this study?

How do you intend to implement these recommendations?

Answer 37: The Operations Task Force has essentially completed its work and is in the process of reviewing its conclusions with NASA management and the Oversight committee, which was established to provide a critical review of those conclusions. The Administrator reviewed the recommendations on May 15, 1987. On June 1 and 2, separate briefings were done for the House and Senate staffs on the preliminary findings of the task force. The complete report will be issued in September 1987.

The basic concepts recommended by the SSOTF have been accepted by the Associate Administrator for Space Station. The key recommendations made were: (1) baseline a functional structure to delineate all elements of operational activities in a specific framework; (2) implement a centralized approach to strategic and tactical control, but a decentralized approach to execution of operations functions; (3) assign "resource envelopes" to users as a way of reducing the number of ground personnel required to operate the Station; (4) establish an operations performance assessment approach; (5) develop specific implementation plans for the development of facilities necessary for ground operations; (6) implement a comprehensive and disciplined approach to integrated logistics management during the development phase; and (7) make maximum use of system commonality at the "fit and function" level to reduce operations complexities and costs.

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